(12)

AEROSPACE REPORT NO.
TOR-0091(6561-04)-1

Quality Function Deployment in Launch Operations

Prepared by

P. L. PORTANOVA and E. J. TOMEI, JR.
Space Launch Operations

23 November 1990

Prepared for

SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Base
P. O. Box 92960
Los Angeles, CA 90009-2960

Contract No. F04701-88-C-0089

Programs Group

THE AEROSPACE CORPORATION
El Segundo, California

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY 2b DECLASSIFICATION / DOWNGRADING SCHEDULE	3 DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited
4 PERFORMING ORGANIZATION REPORT NUMBER(S) TOR-0091(6561-04)-1	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION The Aerospace Corporation 6b OFFICE SYMBOL (If applicable)	7a NAME OF MONITORING ORGANIZATION Space Systems Division
6c ADDRESS (City, State, and ZIP Code) El Segundo, CA 90245	7b ADDRESS (City, State, and ZIP Code) Los Angeles Air Force Base Los Angeles, CA 90009-2960
8a NAME OF FUNDING / SPONSORING ORGANIZATION Space Systems Division 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F04701-88-C-0089
8c ADDRESS (City, State, and ZIP Code) Los Angeles Air Force Base Los Angeles, CA 90009-2960	10 SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO / PROJECT NO / TASK NO / WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification)
Quality Function Deployment in Launch Operations

12 PERSONAL AUTHOR(S)
Portonava, Peter L. and Tomei, Edmardo J., Jr.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
	FROM ______ TO ______	1990 November 23	

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Total Quality Management Quality Function Deployment Management

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

The goal of the Advanced Launch System (ALS) is a more efficient launch capability that provides a highly reliable and operable system at substantially lower cost than current launch systems. Total Quality Management (TQM) principles are being emphasized throughout the ALS program. A continuous improvement philosophy is directed toward satisfying users' and customers' requirements in terms of quality, performance, schedule, and cost. Quality Function Deployment (QFD) is interpreted as the "voice of the customer" (or user), and it is an important planning tool in translating these requirements throughout the whole process of design, development, manufacture, and operations. This report explores the application of QFD methodology to launch operations, including the modification and addition of events (operations planning) in the engineering development cycle, and presents an informal status of study results to date.

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL	22b TELEPHONE (Include Area Code) / 22c OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Report No.
TOR-0091(6561-04)-1

QUALITY FUNCTION DEPLOYMENT IN LAUNCH OPERATIONS

Prepared

P. L. Portanova
P. L. Portanova, Director
Operations and Integration Directorate
Space Transportation Development Directorate

E. Tomei
E. Joseph Tomei, Jr., Director
Advanced Programs & Studies
Western Test Range

Approved

A. Dwight Abbott
A. Dwight Abbott
Principal Director
Space Transportation Development Directorate

Accession For		
NTIS GRA&I		X
DTIC TAB		☐
Unannounced		☐
Justification		
By		
Distribution/		
Availability Codes		
Dist	Avail and/or Special	
A-1		

The information in a Technical Operating Report is developed for a particular program and is therefore, not necessarily of broader technical applicability.

ACKNOWLEDGMENTS

The authors are grateful for the support and encouragement that were provided during this study. In particular, special thanks go to Col J. R. Wormington, Program Director, Advanced Launch Systems, at whose request this study was undertaken, and who also provided much needed support and suggestions. Also, valuable contributions and helpful assistance to data collection for this study were provided by T. Cross and M. R. Moore of the Advanced Launch Systems Joint Program Office, Maj W. K. Eberly of SPACECOM/XRSL, and Maj M. O. Simpkins of SPACECOM/XRSD.

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

1.1 BACKGROUND

Since the beginning, the space launch industry has endured substantial variances in meeting schedules and even greater variances in meeting cost objectives. Technical performance has generally been more important than schedules, and both were usually more important than cost. Due to the high technology orientation of launch systems, the performance requirements were paramount. The need to achieve the last few percent of performance became a goal that was both costly and counter productive in terms of reliability and dependability. Today, the military customer is demanding that emphasis be placed on meeting schedules and cost objectives without foregoing technical excellence. The new environment for current space programs therefore dictates a concentrated effort on the part of management and engineering to investigate modern, innovative approaches for development of the Advanced Launch System (ALS).

1.1.1 The Mission of Management

The professional manager, the person who must apply particular managerial concepts and insights to specific situations, needs a way of addressing his overall task. Of necessity, the manager is primarily interested in satisfying the customer with quality products or services. To this end, the manager wants the management principles they intend to employ to be clearly stated in an integrated framework directly applicable to their concerns. The Deming approach to management (Ref. 1) provides a practical framework for assessing the management task and applying modern, effective management techniques.

These modern management concepts are being aggressively applied in many commercial firms to improve their market competitive edge. Recently, some U.S. firms, including companies from the automotive, electronics, and aircraft industries, have been successful using a Total Quality Management (TQM)

concept based on Deming management principles. The need for effective managers is obviously as pressing in military and space-related industrial organizations as it is in the commercial market. Increasing demands caused by DoD budget constraints, space system design complexity, and the rising costs of future space systems all intensify the necessity for able managers and competent technical personnel.

For many years, managers were widely regarded as individuals who merely adapted to their situation. Today's manager must go beyond simply adjusting to the situation and instead, they must be proactive and provide a dynamic, innovative force. The purpose of using the Deming management principles is to transform the traditional American management style to a modern, aggressive approach, even if it requires a whole new management structure from top to bottom.

1.1.2 The Need for Quality Function Deployment

Quality Function Deployment (QFD) is a promising method of applying current TQM concepts in implementing modern management techniques. Literally, QFD is a translation from the Japanese Kanji characters "Hin Shitsu Ki No Ten Kai." As shown in Figure 1, this illusive entity called QFD has several interpretations. The Japanese have selected "Quality Function Deployment" as the most appropriate translation, but this is somewhat unfortunate since quality has different connotations in the American culture. However, by examining each pair of characters individually, better insight into the meaning of QFD may be found. In the U. S. culture, QFD may be thought of as "a system for translating customer requirements into appropriate company requirements at each stage from research and development through engineering and manufacturing to deployment and implementation," and QFD can then be interpreted as "the voice of the customer (or user)." The Strategic Defense Initiative Office (SDIO) and NASA also have funded ALS program activities and are potential users. Because Air Force Space Command is the author of the ALS System Operational Requirements Document, which served as the primary basis for requirements determination, they are hereafter referred to as the customer.

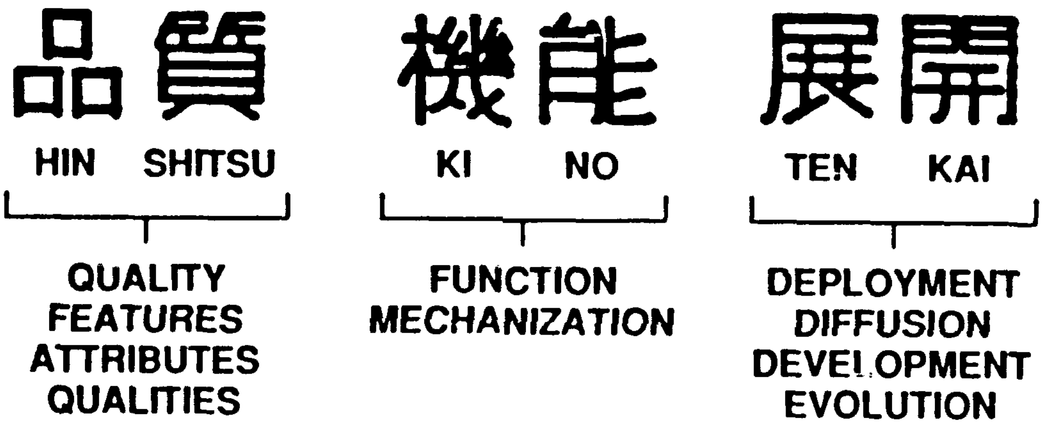

Figure 1. Quality Function Deployment
Source: American Supplier Institute

1.1.3 QFD Methodology

QFD is a technique for systematically analyzing the customer's (Space Command) perceptions of what constitutes a highly reliable and operable system and functionally breaking down those attributes to identify the critical characteristics that determine an efficient launch system capability. In applying the principles of QFD, a series of matrices or charts are developed with emphasis on the one commonly known as the "House of Quality" (because of its roof-like format), which identifies and translates the most critical information.

There are four key types of charts or phases that are developed during the QFD process:

- Product Planning
- Part Deployment
- Process Planning
- Production Planning.

QFD is a team process, with each planning phase being performed by multi-disciplined teams of varying composition providing expertise in all areas including vehicle design, development, and operations.

1.2 OBJECTIVES

A great deal has been written and said during the past few years about Total Quality Management and the use of Quality Function Deployment (QFD) in product development. However, applying QFD to launch operations has never been attempted. It is anticipated that QFD can play a significant role in the future of launch operations, but it is important to examine this role realistically so that workable plans and requirements are translated into viable launch systems which will satisfy the needs of the customer. The objectives of this report are to explore the application of QFD methodology to launch operations, and to test this procedure against the Air Force Space Command operational requirements.

2. QUALITY FUNCTION DEPLOYMENT OVERVIEW

Quality Function Deployment (QFD) is a planning tool to improve the process for introducing new or upgraded products which translates the customer requirements from concept to the factory floor and beyond. QFD employs a series of matrices and charts, which, upon initial examination, may appear overly detailed and somewhat intimidating. However, QFD is a relatively straightforward but complex and time-consuming process which can offer significant returns in improved management and cost savings when properly applied.

In researching the QFD process, a number of different approaches were found for applying the principles. The QFD methodology chosen for use in launch operations was based on presentations of the American Supplier Institute in their three-day QFD workshop (Ref 2).

The research for this QFD study was performed in two sequential steps. The first step consisted of an historical review of the evolution of TQM including QFD. To determine current QFD opportunities, various ALS documents and periodicals were researched, and this literature research initiated the development of a series of user questionnaires. In the second step, the Product Planning Matrix or House of Quality was developed using data from the questionnaires and from brainstorming sessions with key ALS personnel.

In applying QFD, the initial phase involves the creation of a Product Planning Matrix which displays a great deal of information and is called the House-of-Quality matrix due to its roof-like format as shown in Figure 2. It is important that this chart be thoroughly understood, because it integrates all those data regarding the product or service and represents the foundation of QFD. The many areas of the House are described in paragraphs 2.1 through 2.8 and are followed by a discussion of the composite nature of the various requirements.

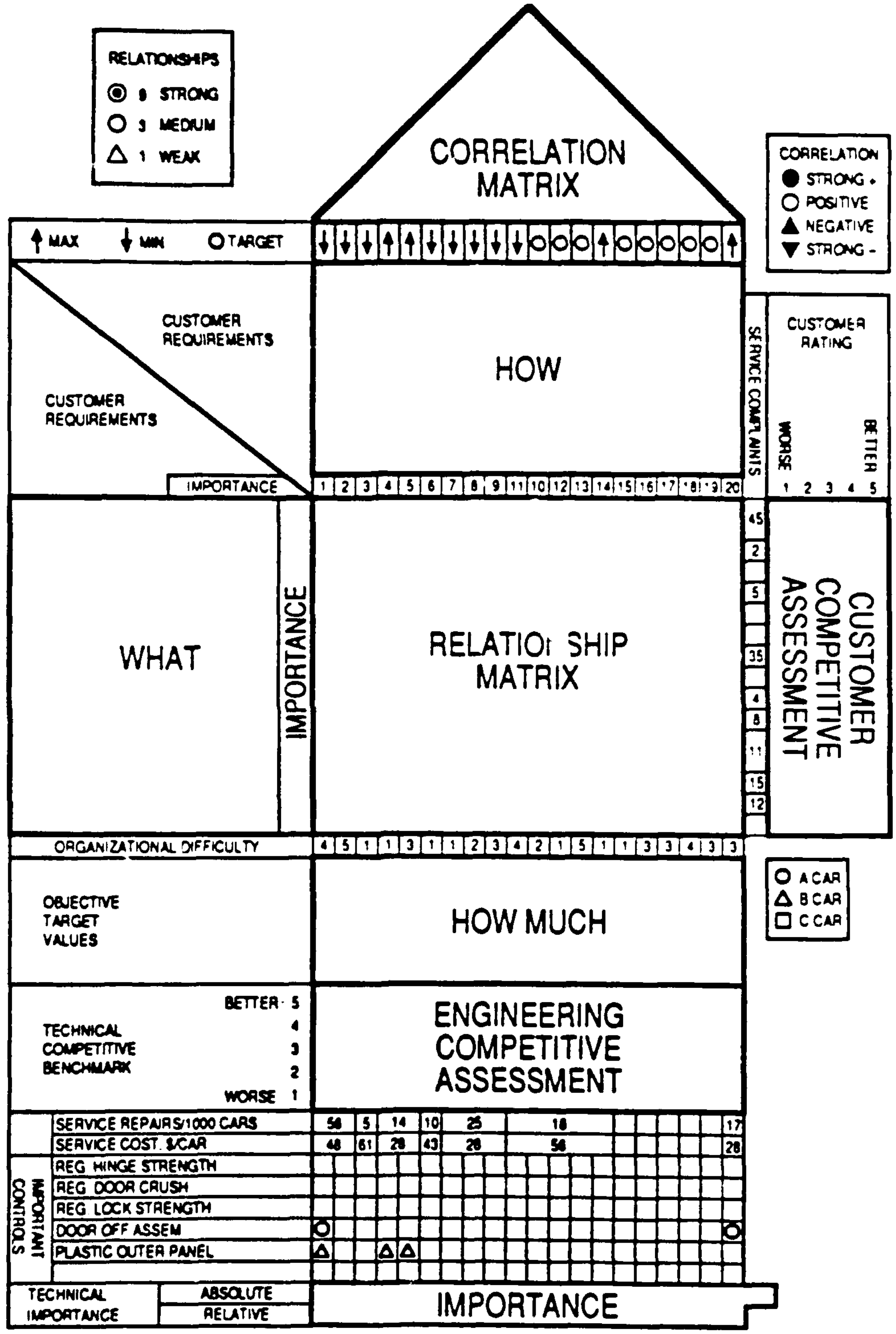

Figure 2. Quality Function Deployment Product Planning Matrix
Source: American Supplier Institute

2.1 VOICE OF THE CUSTOMER

The QFD process starts with a list of objectives representing the "WHATs" that must be accomplished. This list constitutes the customer requirements and is referred to as the "Voice of the Customer." Usually, this list is made up of very general or purposely vague items which are difficult to implement directly, and it contains verbalized customer needs listed verbatim without embellishment or interpretation. These customer WHATs are organized in rows on the left side of the House.

2.2 DESIGN REQUIREMENTS

The list of WHATs is translated into engineering detail by listing one or more "HOWs" for each WHAT. By this method, the customer requirements are translated into design requirements. In practice, some of the HOWs may affect more than one WHAT or may adversely affect one another. These engineering HOWs are organized as columns in the ceiling area of the House.

2.3 RELATIONSHIPS

The relationships between WHATs and HOWs are found at the intersection of the rows and columns. Also shown at the intersections are the strengths of each relationship symbolized by "O" for a Strong Relationship, "o" for a Medium-Strength Relationship, "x" for a Weak Relationship, and a blank for No Relationship. This not only provides a simplified interpretation for a complex relationship, but also provides an easy cross-check. As an example, blank rows or columns are an immediate indication that the translation of WHATs into HOWs has been inadequate, a customer WHAT has been ignored, or an engineering HOW is not needed.

2.4 MEASUREMENTS

The next key element is the Measurements for the HOWs, often called the "HOW MUCHs," which provide an objective means of assuring that requirements have been met and targets for further detailed development. These objective

targets provide a means of determining progress and avoiding "Swags" or "opinion-eering." Therefore, if the HOW MUCHs are not measurable, it provides an indication that there is a lack of detail in the definition of the HOWs. These HOW MUCHs are located in the basement area of the House.

2.5 THE HOUSE OF QUALITY

The four key elements described above (WHAT, HOW, Relationsnips, and HOW MUCH) form the structure of QFD. However, there are several useful extensions to the basic QFD chart which greatly enhance its usefulness, and their use depends on the content and purpose of each specific project. The purpose of the Correlation Matrix with its roof-like format is to identify areas where trade studies and analysis may be required. This matrix, which is usually located above the HOWs, uses symbols to designate the strength of the relationships: "O" for Positive, "●" for Strong Positive, "X" for Negative, and "XX" for Strong Negative. Positive correlations are those in which one HOW supports another HOW, while negative correlations are those in which one HOW adversely affects the achievement of another HOW. Early identification of these conflicts is extremely important, because they represent conditions pointing toward additional analysis and trade studies. Trade studies which are not promptly identified and resolved will often lead to unfulfilled requirements, despite best efforts in all other areas.

2.6 COMPETITIVE ASSESSMENT

The Competitive Assessments are a pair of graphs which depict item by item how competitive products compare. These assessments are made for the WHATs and the HOWs. The Competitive Assessment of the WHATs is basically a Customer Competitive Assessment and should therefore utilize customer-oriented information. It is critical to the success of the assessments to understand the customer's perception of their product relative to its competition. On the other hand, the Competitive Assessment of the HOWs is primarily an Engineering Competitive Assessment, and the best engineering expertise available should be utilized directly in this process in order to gain the most complete understanding of competitive products.

The Competitive Assessment can also be useful in establishing the values of the objectives or HOW MUCHs to be achieved by selecting values which are competitive for each of the most important issues. This method provides a valuable cross-check and may uncover errors in engineering judgment. If the HOWs have been properly evolved from the WHATs, the Competitive Assessments should be reasonably consistent. Conversely, a blank row indicates a lack of response to a customer need; a blank column suggests an engineering "overkill," because there is no customer need. The WHAT and HOW items which are strongly related should also exhibit a complementary relationship in the Competitive Assessment. The WHAT Competitive Assessment is found on the right side, and the HOW Competitive Assessment is found in the subbasement.

2.7 IMPORTANCE RATING AND ORGANIZATIONAL DIFFICULTY

The Importance Rating is useful for prioritizing efforts, and Organization Difficulty is helpful in making tradeoff decisions. Numerical tables or graphs will depict the relative importance of each WHAT or HOW to the desired end result. The WHAT importance rating is established based on the customer assessment. It is expressed as a relative scale of 1 to 10 with the higher numbers indicating greater importance to the customer. It is vital that these values truly represent the customers view rather than internal company beliefs. These ratings are found by the left wall and in the floor of the House.

The Technical Importance (Absolute) for the HOWs is calculated using weights assigned to the Relationship symbols, such as 'O' (Strong) = 9, "o" (Medium) = 3, and "x" (Weak) = 1. For each column (HOW), the WHAT importance value is multiplied by the symbol weight, producing a value for each Relationship. Summing these values vertically defines the HOW importance value.

The Technical Importance (Relative) for the HOWs provides a relative importance (ranking) of each HOW in achieving the collective WHATs. These values have no direct meaning, but rather are to be interpreted by comparing the relative magnitudes. It is important that one is not blindly driven by

these numbers. The numbers are intended to help but not constrain, and they provide further opportunities to cross-check the thought process.

The absolute and relative importances are found at the very bottom of the House.

2.8 QUALITY FUNCTION DEPLOYMENT PHASES

In order to translate the voice of the customer throughout the company from design through production, a phased approach was developed. These phases systematically cascade the critical information through a series of matrices. This is done by taking the HOWs of the previous chart and translating them into the WHATs of the next chart (see Figure 3). The HOW MUCH values are likewise transferred to make sure the objective values are not lost in the process.

The process is carried out so that each objective is defined at an actionable level. The HOWs which are transferred to the next level are selectively limited to those items which are identified as critical. That is, only those items of greatest importance, risk, or difficulty or which are new should be taken to the next phase in QFD.

The four phases employed in the QFD process mirror the four phases of product development and are titled:

Phase 1	Product Planning
Phase 2	Part Deployment
Phase 3	Process Planning
Phase 4	Production Planning.

Figure 4 demonstrates how the QFD process translates each set of requirements from one phase to the next. Each phase is represented by a different matrix, but the processes used for each are similar.

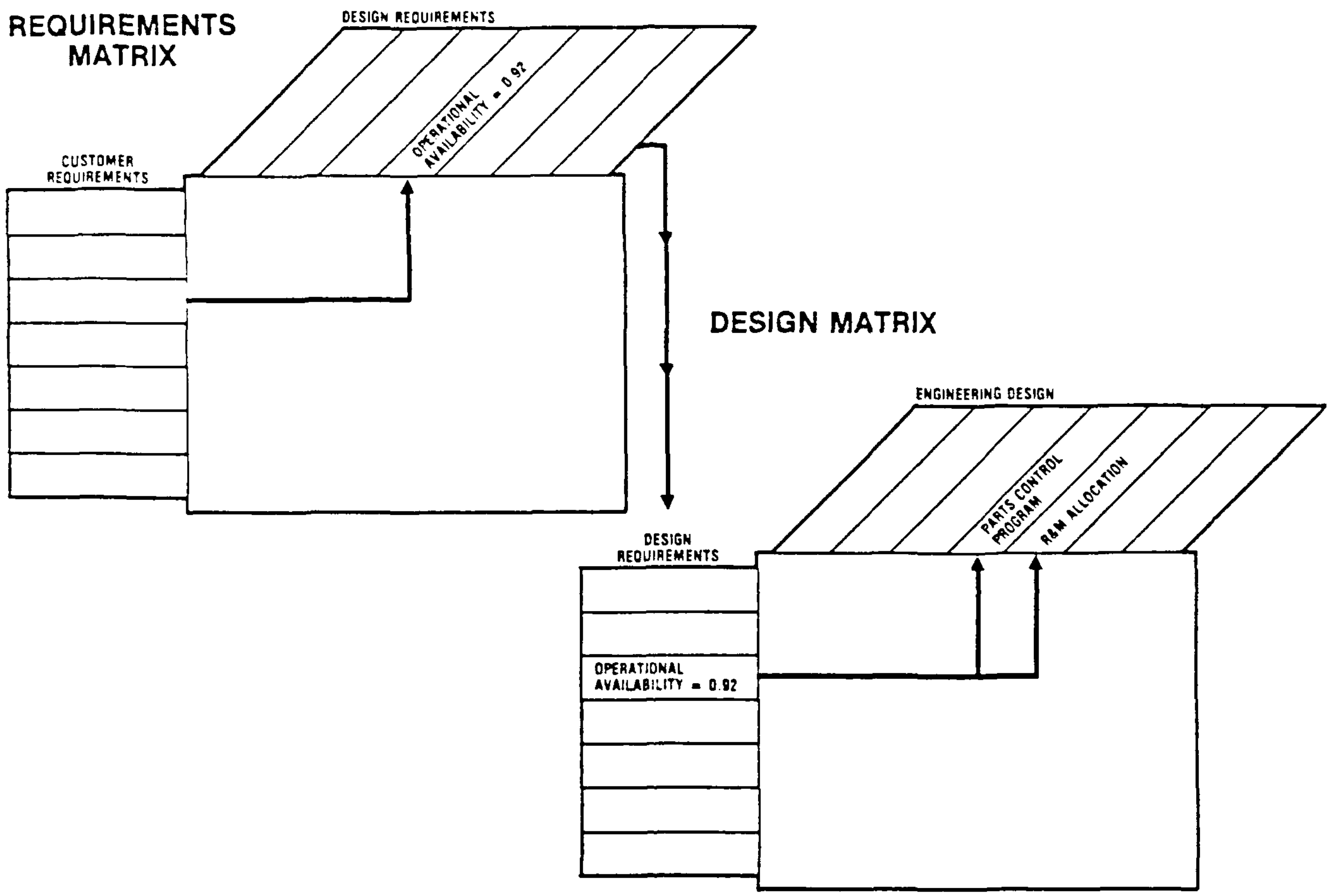

Figure 3. Requirements Translation
Source: American Supplier Institute

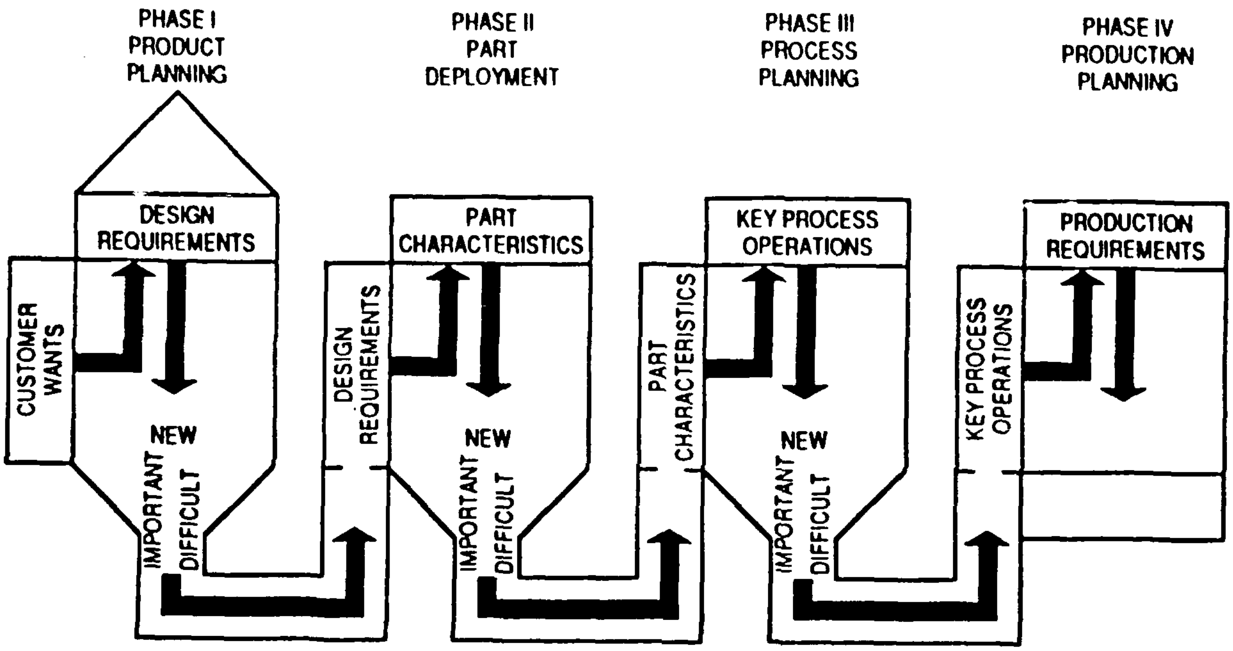

Figure 4. Four Phases of QFD
Source: American Supplier Institute

3. QFD AND LAUNCH OPERATIONS

3.1 OVERVIEW OF THE METHODOLOGY

This section discusses the application of QFD methodology to space launch operations. In researching the QFD approach, only a few examples were found in which the principles were applied. These typically involved specific parts and components, such as a car door or an avionics module (Ref 3), or a small system such as an air-to-ground missile (Ref 4). Also, the more complex of these were not developed to lower matrix levels. Illustrative examples which addressed processes or services similar to launch operations, particularly in terms of a new system design, could not be found. In addition, it was apparent early-on that the complexity involved in this subject matter exceeded the level recommended for an initial project.

As a result of these complications, it was decided that the proper approach would be to perform an exploratory study using limited resources which would permit examination of the merits of the QFD process for this application. If successful, it would then be possible to define the process by preparing an example which could serve as a model for continued work.

This project was undertaken in support of the Advanced Launch System (ALS) program, and the QFD methodology was used to trace the customer's requirements from concept through implementation. The user, Air Force Space Command, is the customer of the Space Systems Division/NASA Joint Program Office, which is the developer of the ALS. Because the ALS system has the joint attributes of both a product (launch systems) and a process (launch operations), modification of the usual QFD process was anticipated.

3.2 PRODUCT PLANNING MATRIX EXAMPLE

As described earlier, the first steps in the QFD process are to define the customer requirements and the design requirements so that a planning or

requirements matrix can be developed. In the first attempt, this was done by examining the current program documents which seemed to offer a natural source for identifying the requirements. The Air Force Space Command (AFSPACECOM) requirements for ALS are contained in the System Operational Requirements Document for ALS (SORD)(Ref 5). The Air Force/NASA ALS Joint Program Office (JPO) has defined the ALS requirements including design in a System Requirements Document (SRD)(Ref 6). The requirements data contained in the customer SORD were extracted and tabulated as WHATs as shown in Table 1. Likewise, the design data contained in the SRD were extracted and tabulated as HOWs as shown in Table 2. These lists of WHATs and HOWs were then interpreted as customer requirements and design requirements, and a preliminary Product Planning Matrix was prepared.

Once this point was reached, assessment of the chart was begun to determine what additional information would be needed to complete the matrix. In doing this, it was discovered that the "natural" process which was being followed was not consistent with the QFD methodology. For example, the Customer Requirements column (or WHATs) is supposed to represent the voice of the customer in a general or unquantified way. Instead, in the initial version, the Customer Requirements List contained numerous specific values. Similarly, the Design Requirements List, which should have quantifiable target values, is less quantifiable as described and looks more like parts of components than design features.

At this point, it appeared that this matrix had attributes more closely resembling a Parts Deployment Matrix (i.e., the next level down) rather than the intended Product Planning Matrix. As a result, a new matrix was prepared by redesignating the original list of the WHATs as HOWs, and a new set of Customer Requirements was prepared. These new WHATs were intentionally selected for vagueness and lack of quantifiable values, and the new Customer Requirements were not made up but were extracted without embellishment from various locations within the text of the SORD and then recategorized into secondary and primary designations. The new design requirements (HOWs) were then derived from the original list of Customer Requirements along with additional requirements that seemed appropriate. These requirements were slightly reworded as necessary.

Table 1. Systems Operational Requirements Document

PRIMARY	SECONDARY	TERTIARY WHATS (FIRST ATTEMPT)	SYSTEMS OPERATIONAL REQUIREMENTS DOCUMENT (SORD)
SYSTEM PERFORMANCE	COST	SIGNIFICANTLY REDUCE COSTS BE AFFORDABLE	
	MISSION CAPABILITY	2000: LEO 50,000– 90,000 LB GEO 10,000– 15,000 LB POLAR 30,000– 60,000 LB TOTAL 400,000 LB/YR VOLUME 15 FT × 60 FT 2004: LEO 4,000–150,000 LB GEO 4,000– 15,000 LB POLAR 1,000–110,000 LB TOTAL 2,000,000 LB/YR VOLUME 15 FT × 60 FT 2008: LEO 4,000–220,000 LB GEO 4,000– 15,000 LB POLAR 1,000–160,000 LB TOTAL 5,000,000 LB/YR VOLUME 50 FT × 165 FT	
	OPERABILITY	BLUE SUIT OPERATION STANDARDIZED LAUNCH VEHICLE INTERFACES STANDARDIZED PAYLOAD INTERFACES SIMPLIFIED PAYLOAD INTEGRATION REDUCE LAUNCH CONSTRAINTS NORMALIZE AND STREAMLINE OPERATIONS FUELING/DEFUELING IN ≤24 HRS MINIMIZE IMPACT OF ENVIRONMENT	
	CONTROL	DoD COMMAND AND CONTROL AUTHORITY	

Table 1. Systems Operational Requirements Document (Continued)

PRIMARY	SECONDARY	TERTIARY WHATS (FIRST ATTEMPT)	SYSTEMS OPERATIONAL REQUIREMENTS DOCUMENT (SORD)
READINESS	AVAIL.	AVAILABILITY TO BE BETTER THAN 90%	
	DEPEN.	DEPENDABILITY TO BE BETTER THAN 95%	
	RESPON-SIVENESS	LAUNCH ON SCHEDULE 6-10 TIMES PER YR LAUNCH ON NEED WITH 30-DAY NOTICE PAYLOAD CHANGEOUT IN ≤5 DAYS LAUNCH SURGE OF 7 SATELLITES IN ≤5 DAYS REGENERATE LAUNCH SURGE CAPABILITY IN ≤60 DAYS	
MISSION R&M	RELIABILITY	RELIABILITY TO BE BETTER THAN 98% NO SINGLE POINT FAILURES	
	RECOVERY	ACCOMMODATE AT LEAST A 35% INCREASE IN LAUNCH RATE	
	STANDDOWN	PROBABILITY OF EXCEEDING 3 MONTHS STANDDOWN TO BE ≤5%	

Table 1. Systems Operational Requirements Document (Continued)

PRIMARY	SECONDARY	TERTIARY WHATS (FIRST ATTEMPT)	SYSTEMS OPERATIONAL REQUIREMENTS DOCUMENT (SORD)
LOGISTICS R&M	MAINTAIN-ABILITY	BLUE SUIT OPERATION MINIMUM ON-PAD MAINTENANCE NO INTERMEDIATE MAINTENANCE LAUNCH PAD TURNAROUND IN ≤6 DAYS EASE OF FAULT DIAGNOSIS SIMPLIFIED & STANDARDIZED FAULT IDENTIFICATION EASE OF REPAIR WITH EXPEDITIOUS REPLACEMENT	
	SUPPORT-ABILITY	BLUE SUIT OPERATION TIMELY/SIMPLIFIED LOGISTICS MINIMIZE SINGLE POINT FAILURES MAXIMIZE MULTIPLE SOURCES EASE OF PARTS CHANGEOUT WITH SIMPLIFIED/STANDARDIZED OPERATIONS	
	SURVIVA-BILITY	SURVIVE AS LONG AS NEEDED MINIMIZE EFFECTS OF ALL THREATS	
	SECURITY	SECURITY APPROPRIATE TO PAYLOAD CLASSIFICATION PAYLOAD IDENTITY CONCEALMENT AND PROTECTION	

Table 2. Systems Requirements Document

PRIMARY	SECONDARY	HOWS TERTIARY (FIRST ATTEMPT)	SYSTEMS REQUIREMENT DOCUMENT (SRD)
VEHICLE SYSTEMS	CARGO	ENVIRONMENTAL CONTROL	
		ORDNANCE	
		PAYLOAD FAIRING	
		UPPER STAGE	
		PAYLOAD	
	CORE VEHICLE	AVIONICS: SOFTWARE	
		AVIONICS: HEALTH MONITOR	
		AVIONICS: GUIDANCE	
		AVIONICS: ELECTRONICS	
		AVIONICS: POWER	
		TVC	
		TANKS	
		ORDNANCE	
		ENGINES	
		RECOVERY MODULE	
	SOLID BOOSTER	RECOVERY SYSTEM	
		TVC	
		POWER	
		ORDNANCE	
		SOLID MOTOR	
	LIQUID BOOSTER	POWER	
		TVC	
		P/A MODULE	
		TANKS	
		ORDNANCE	
		ENGINES	

Table 2. Systems Requirements Document (Continued)

PRIMARY	SECONDARY	TERTIARY HOWS (FIRST ATTEMPT)	SYSTEMS REQUIREMENT DOCUMENT (SRD)
LAUNCH SYSTEMS	TRANSPORTATION	PROCEDURES MANPOWER UTILITIES POWER TRANSPORTATION FACILITIES MOBILE LAUNCH PLATFORM CHANNELS RAILWAYS ROADWAYS VESSELS PRIME MOVERS TRANSPORTERS	
	RECOVERY	PROCEDURES MANPOWER RECOVERY EQUIPMENT HANDLING EQUIPMENT UTILITIES POWER ENVIRONMENTAL CONTROL SAFING EQUIPMENT TRACKING EQUIPMENT RECOVERY FACILITY	
	LAUNCH OPERATIONS	ENVIRONMENTAL PROTECTION PROCEDURES MANPOWER EMERGENCY EQUIPMENT LAUNCH FACILITY SECURITY SYSTEM UTILITIES POWER ENVIRONMENTAL CONTROL HEALTH MONITOR SYSTEM SOFTWARE ACCESS EQUIPMENT LAUNCH MOUNT SERVICING SYSTEM EQUIPMENT CONTROL SYSTEM EQUIPMENT MISSION CONTROL FACILITY LAUNCH CONTROL FACILITY	
	CARGO INTEGRATION	PROCEDURES MANPOWER HEALTH MONITOR SYSTEM TEST EQUIPMENT ACCESS EQUIPMENT HANDLING EQUIPMENT INTEGRATION FACILITY SECURITY SYSTEM UTILITIES POWER ENVIRONMENTAL CONTROL	
	LV INTEGRATION	PROCEDURES MANPOWER SECURITY SYSTEM UTILITIES POWER HEALTH MONITOR SYSTEM ACCESS EQUIPMENT TEST EQUIPMENT HANDLING EQUIPMENT INTERFACE UMBILICALS INTEGRATION FACILITY	
	ASSEMBLY AND C/O	PROCEDURES MANPOWER SECURITY SYSTEM UTILITIES POWER HEALTH MONITOR SYSTEM ACCESS EQUIPMENT HANDLING EQUIPMENT CHECKOUT EQUIPMENT ASSEMBLY FACILITY	

Table 2. Systems Requirements Document (Continued)

PRIMARY	SECONDARY	HOWS TERTIARY (FIRST ATTEMPT)	SYSTEMS REQUIREMENT DOCUMENT (SRD)
INFORMATION SYSTEMS	MODELING	OPERATIONS MODEL RELIABILITY MODEL COST MODEL PERFORMANCE MODEL ALSYM	
	INFORMATION MANAGEMENT	DECISION SUPPORT SYSTEM SOFTWARE UTILITIES POWER DATA / COMPUTER FACILITIES UNIS ACCESS CONFIGURATION MANAGEMENT PROCEDURES MANPOWER	
	DATA PROCESSING	COMPUTER SYSTEM DISPLAYS SOFTWARE AUTOMATION EXPERT SYSTEMS	
	DATA COLLECTION	ORBITAL STATIONS GROUND STATIONS CABLE PLANT INSTRUMENTATION SYSTEM CAD / CAM HEALTH MONITOR SYSTEM INPUT SYSTEM TELEMETRY SYSTEM OPTICAL SYSTEM	
	DATA STORAGE	LOGGERS OSCILLOGRAPHS MAGNETIC TAPES FILM OPTICAL DISCS VIDEO TAPE MAGNETIC DISCS MASS MEMORY CHART RECORDERS	
	COMMUNICATIONS	PROCEDURES POWER COMMUNICATIONS FACILITIES MANPOWER LASER LANDLINE RF NETWORK DATA VIDEO AUDIO	

Table 2. Systems Requirements Document (Continued)

PRIMARY	SECONDARY	HOWS TERTIARY (FIRST ATTEMPT)	SYSTEMS REQUIREMENT DOCUMENT (SRD)
MANAGEMENT SYSTEMS	CONTROL	COMMAND AND CONTROL MISSION READINESS ENGINEERING	
	PLANNING	PROCEDURES SCHEDULING PLANNING	
	BUDGET	EXPENDITURES COST ESTIMATING CONTRACTING	
SUPPORT SYSTEMS	INFRASTRUCTURE	EMERGENCY RESPONSE REAL PROPERTY SUPPORT FACILITIES TRANSPORTATION UTILITIES POWER TEST RANGE	
	PRODUCTION	PROCEDURES QUALITY CONTROL PROCESSING SYSTEM MANPOWER CONFIGURATION CONTROL PRODUCTION CONTROL FABRICATION TOOLING MANUFACTURING PLANT	
	LOGISTICS	WASTE MANAGEMENT CONSUMABLES PROCEDURES MANPOWER TRAINING MAINTENANCE AND REPAIR CLEANING INSPECTION AND TEST SUPPLY	

3.2.1 Customer Requirements

Since the new planning matrix seemed to better satisfy the QFD approach than did the original attempt, it was concluded that the SORD provides a useful source for a combination of customer requirements plus some design requirements. However, the remaining Operations Design Requirements were not defined in either the SORD or SRD and therefore had to be derived. This final list was not developed all at once but instead took several iterations over a period of time. An explanation of how these design requirements were ultimately developed will be discussed later.

The next step in the process included gathering the initial customer information. After completing the Customer Requirements List, a survey was prepared in order to obtain source data for the study (See Appendix A). This was not intended as a marketing survey per se but merely a request for customer ratings of the relative importance of these selected requirements along with their relative rating of competitive systems. The competitive launch systems chosen were Ariane, Atlas, Delta, Shuttle, and Titan. Although some of these systems are not truly competitive for a number of reasons, this approach did allow a comparative analysis which proved useful in developing the planning matrix. This survey was submitted to AF SPACECOM personnel, and the results were used to complete the customer portion of the matrix.

3.2.2 Design Requirements

Developing the design requirements data was more complex. The initial set of requirements was divided into primary groupings of operating factors and performance factors. The majority of performance factors were defined by specific parameters which were used to identify specific target values. In the case of the operating factors, however, a large percentage of these requirements involve undefined parameters related to operations tasks. Where specific target values were available, they were used. Otherwise, interim placeholder values were inserted. These values were typically defined in terms of effort which must be controlled in order to satisfy the chief customer requirements of operability and affordability. Depending on the

factors involved, they were identified as either maximum limit values or allowable target values, which were further expressed in terms of manhours, delay time, or timespan. At this point, it could be seen that the key to implementing the QFD process in this application would be the ability to successfully convert the Voice-of-the-Customer requirements into legitimate operating design targets which could be traced through the development process.

For the initial iteration then, placeholders were used throughout. This allowed the QFD evaluation process to continue while parallel operations studies developed the appropriate target values. These operations studies are being conducted in two parts. One study is an ongoing modeling effort which is intended to define the ALS operations processes and allows development of the task resources and support requirements to perform each function. The other study is based on current launch systems performance in which operations data are being collected and used to provide target parameters in terms of resources, timelines, and delay factors. These two results will then be merged to define discrete target values for each identified operating factor. Since this is an ongoing iterative process, these placeholders will be used in the QFD process until both the appropriate operations design factors and target values are defined.

3.2.3 Relationships

Following identification of the customer and design requirements and preparation of the matrix table, the requirements relationships were established by determining the degree to which each design target satisfied each customer requirement. This was a team process where multiple relationship tables were compared and the strengths rationalized. It was observed that this was an inexact process which requires additional refinement, but it did serve two useful purposes: one was establishing a baseline of relative merit for each factor, and the other was fostering a fresh look at the interaction between requirements. During this process, several new factors were identified and included in the Design Requirements List, and the context of each requirement was better defined. For the purposes of this exploratory QFD project, launch processing operations were

considered to begin at the end of final assembly and launch operations at the end of launch vehicle integration.

3.2.4 Correlations

Following the first draft of the Requirements Relationship Matrix, the Design Requirements Correlation Assessment was performed. The respective design requirements were each compared to determine the degree of positive supporting or negative conflicting requirements. These correlations were similarly completed by comparing independent attempts and the differences rationalized. The results were input to the matrix above the design requirements. These results indicate numerous complementary requirements along with a few conflicts, which represent potential subjects for appropriate trade studies. These trades are identified as first or second order, and examples are listed in Tables 3 and 4.

3.2.5 Competitive Assessments

At this point, the first cut at a Product Planning Matrix was nearly complete. To gather the necessary additional information, another survey questionnaire was prepared (Appendix B) which represented an in-house assessment of the design requirements and their associated target values. This was done by requesting project engineers to submit their evaluation of the ability of the respective competitive launch systems to meet the planned targets (as yet unquantified). The launch systems evaluated were the same five which were addressed in the customer survey. In addition, each individual was asked to assess the relative risk for the ALS program to meet the same target. Admittedly, this initial assessment is purely subjective and not particularly scientific. However, when quantified competitive system data are developed, they will be used to regrade the results, since this is merely an exploratory example for judging the merits of the QFD technique.

The competitive assessments and customer competition ratings were used to check the first set of requirements relationship values. This check was very beneficial in that several corrections were made as a result.

Table 3. First-Order Trade Studies

P/L Integration Effort	vs	P/L Closeout-to-Launch Limit
P/L Integration Effort	vs	Security Requirements
Standardized LV Interfaces	vs	Year 2004 Missions and Year 2008 Missions
Standardized P/L Interfaces	vs	Year 2004 Missions and Year 2008 Missions
Test & Checkout Effort	vs	Integrated Test Effort
Test & Checkout Effort	vs	P/L Closeout-to-Launch Limit
Launch on Need Requirements	vs	Security Requirements
Surge Requirements	vs	Security Requirements
Surge Requirements	vs	Pad Turnaround Limit

Table 4. Second-Order Trade Studies

LV Integration Effort	vs	Test & Checkout Effort
LV Integration Effort	vs	Integrated Test Effort
LV Integration Effort	vs	P/L Closeout-to-Launch Limit
LV Integration Effort	vs	Launch Ops Limit
LV Integration Effort	vs	On-Pad Maintenance Effort
LV Integration Effort	vs	Logistics Effort
LV Integration Effort	vs	Reliability Requirements
P/L Integration Effort	vs	Test & Checking Effort
P/L Integration Effort	vs	Integrated Test Effort
P/L Integration Effort	vs	Identification Concealment
P/L Integration Effort	vs	Launch Ops Effort
P/L Integration Effort	vs	On-pad Maintenance Effort
P/L Integration Effort	vs	Logistics Effort
P/L Integration Effort	vs	Reliability Requirements
P/L Integration Effort	vs	Threat Resistance

Table 4. Second Order Trade Studies (Continued)

Launch Constraints	vs	Timely Logistics
Launch Constraints	vs	Security Requirements
Fuel/Defuel Limits	vs	Hazardous Clear Ops Limit
Environmental Impacts	vs	Range Support Effort
P/L Changeout Limit	vs	Identification Concealment
P/L Changeout Limit	vs	P/L Closeout-to-Launch
Test & Checkout Effort	vs	Launch Ops Effort
Test & Checkout Effort	vs	On-Pad Maintenance
Test & Checkout Effort	vs	Reliability Requirements
Test & Checkout Effort	vs	Security Requirements
Integrated Test Effort	vs	Launch Ops Effort
Launch Rate	vs	Launch on Need Requirements
Launch Rate	vs	Surge Requirements
Launch Rate	vs	Recovery Requirements
Launch on Need Requts	vs	Identification Concealment
Surge Requirements	vs	Identification Concealment
Re-Surge Requirements	vs	Identification Concealment
Re-Surge Requirements	vs	Survivability Requirements

Table 4. Second Order Trade Studies (Continued)

Re-Surge Requirements	vs	Threat Resistance
Re-Surge Requirements	vs	Security Requirements
P/L Closeout-to-Launch Limit	vs	Security Requirements
Timely Logistics	vs	Logistics Effort
Logistics Effort	vs	Multiple Sourcing
Logistics Effort	vs	Availability Requirements
Logistics Effort	vs	Dependability Requirements
Multiple Sourcing	vs	Reliability Requirements
Mission Ops Effort	vs	Security Requirements
Range Support Effort	vs	Security Requirements
Availability Requirements	vs	Security Requirements

3.2.6 Importance

After making these corrections, the Product Planning Matrix was essentially finished. The last remaining step for this iteration was to calculate the absolute values of technical importance and convert them to relative values. In addition, a few controls were identified and included for further consideration where these factors applied to the design. The initial Product Planning Matrix is shown in Figure 5.

3.3 PART DEPLOYMENT MATRIX

After completion of the Product Planning Matrix, the procedures defined in the QFD methodology are used to transform the critical design requirements into critical component part characteristics. This step, called Part Deployment, is accomplished by first closely examining the Product Planning Matrix results and then transferring those design requirements deemed critical to satisfying the customer requirements, along with any other critical design items such as high risk, new technology, etc. These selected Critical Design Requirements become the WHATs of a new matrix and are entered in the left column similar to the customer requirements of the previous matrix.

In this application, developing the part characteristics which are to be driven by the Critical Design Requirements was not straightforward. The ALS will consist of several elements, dozens of systems, hundreds of subsystems, thousands of components, and an uncountable number of parts, all of which have some contribution to the overall operability and affordability of the system. On first examination, working at this level appears hopeless. Therefore, in order to reduce the level of detail, ALS subsystems were substituted in place of parts in the Part Deployment Matrix. Though the situation is improved, this still represents a formidable task as shown in the partial listing of ALS systems and subsystems in Table 5.

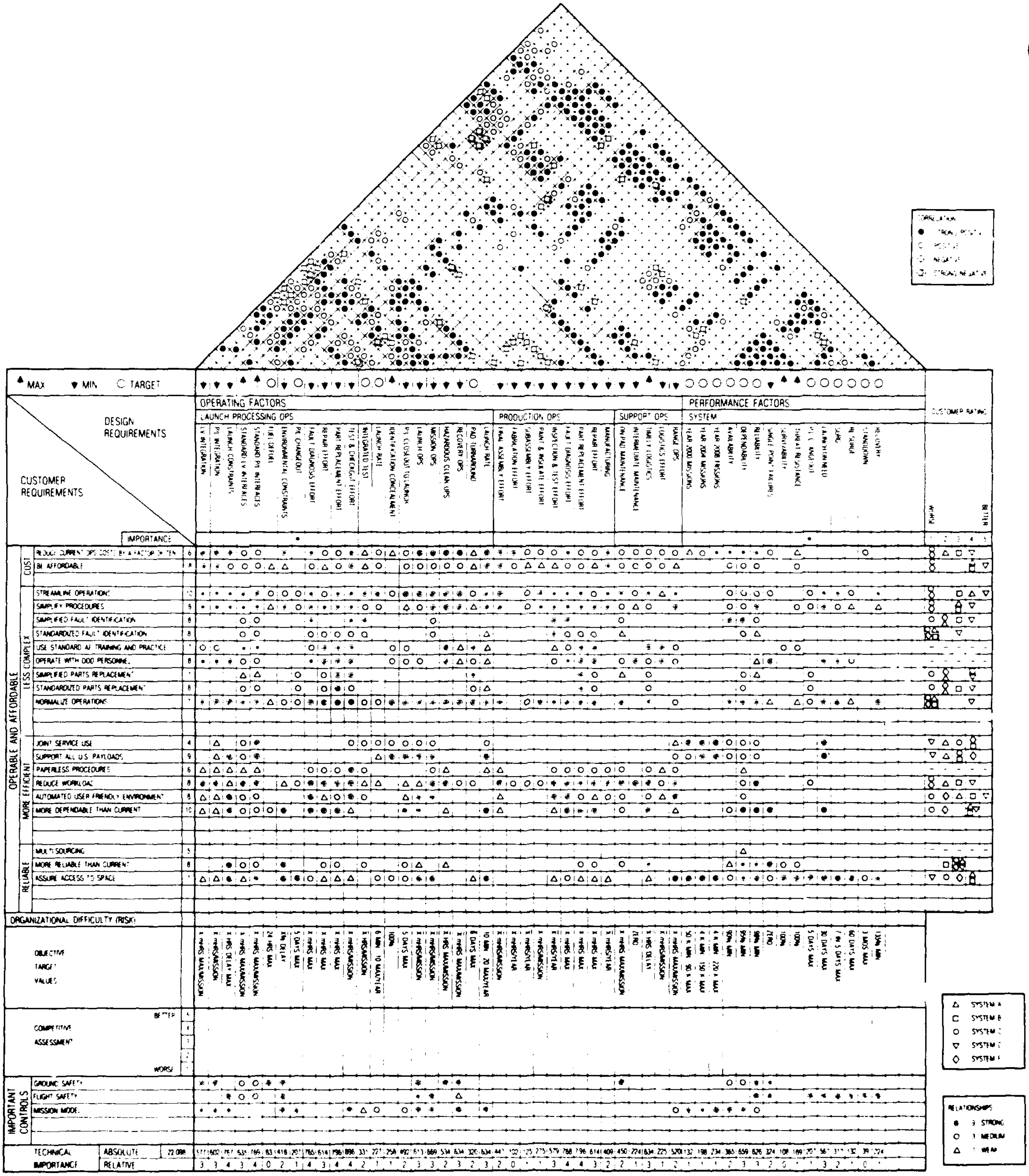

Figure 5. System Planning Matrix

Table 5. ALS Systems and Subsystems

Systems		Subsystems
Vehicle Core	–	Propulsion
		Structures
		Avionics
		Guidance, Navigation & Control
		Power
		Mechanical
		Thrust Vector Control
		Recovery Module
		Instrumentation
		Health Monitor
		Ordnance
		Attitude Control
		Software
		Communication
Vehicle Booster	–	Propulsion
		Power
		Avionics
		Structures
		Mechanical
		Trust Vector Control
		Recovery
		Instrumentation
		Health Monitor
		Ordnance
Cargo	–	Space Vehicle
		Upper Stage
		Payload Fairing
		Ordnance
		Environmental Control
		Power

Table 5. ALS Systems and Subsystems (Continued)

Systems		Subsystems
Launch Processing	-	Propellants
		Handling
		Access
		Power
		Utilities
		Environmental Control
		Environmental Protection
		Pressurization and Purge
		Instrumentation
		Health Monitor
		Mechanical
		Security
		Safety
		Structural
		Facilities
		Waste Management
		Software
		Communication
		Command & Control
		Transportation
		Recovery
Information	-	Communication
		Data Processing
		Data Collection
		Data Storage
		Modeling
		Information Management
		Software
		Procedures

Table 5. ALS Systems and Subsystems (Continued)

Systems		Subsystems
Support	–	Logistics Supply
		Cleaning
		Range Ops
		Training
		Maintenance
		Infrastructure (Host)
Management	–	Configuration Control
		Mission Assurance
		Planning
		Scheduling
		Environmental Monitoring
		Budgets
		Contracts
		Command & Control
		Procedures
		Quality Control
Production	–	Component Assembly
		Inspection & Testing
		Final Assembly
		Finish
		Process Control
		Production Control
		Insulation
		Welding
		Forming
		Machining
		Trimming
		Composites Fabrication
		Environmental Control

In order to proceed with the evaluation, four subsystems were selected for deployment: Vehicle Core Propulsion, Vehicle Core Structures, Launch Processing Propellants, and Launch Processing Handling. They are complementary subsystems taken from both vehicle and launch processing systems and are considered representative of launch operations. Critical subsystem characteristics were then defined for each subsystem. Initially, these characteristics included major components, critical operating parameters, commodities, performance factors, operating factors, etc. All operating characteristics were weighed equally at this point. Table 6 presents an example of a first cut at defining these characteristics for the four subsystems chosen.

These four subsystems and their respective critical characteristics were then taken as the HOWs of the next matrix. This matrix was retitled Subsystem Deployment for our application as opposed to the normal QFD terminology of Part Deployment. However, the approach is identical; i.e., transfer the most important design requirements, select the best design concept, determine the critical characteristics, and identify items for further development. This phase requires a significant system engineering effort, since, as design concepts and alternatives are defined, the characteristics will change. Therefore, the process will be dynamic throughout the preliminary design phase.

For the purposes of evaluating this QFD application, placeholder values were again used for each critical subsystem characteristic value. The actual characteristic values will be determined by preliminary design trades, modeling results, project management decree, etc. Many of these values will not be firmly established until well into the design phase.

Using these preliminary critical subsystem characteristics and the design requirements which flowed down from the Product Planning Matrix, the Subsystem Deployment Relationships were established. This process was similar to that for the previous Product Planning Matrix where the degree to which each subsystem characteristic satisfied the key design requirements was determined. However, since this was done as a demonstration only in order to

Table 6. Example Critical Subsystem Characteristics

System	Subsystem		Critical Characteristics	
Vehicle Core	Propulsion	-	Engine quantity	
			Vacuum thrust	
			Tank volume	(ox, fuel)
			Propellant	(ox, fuel)
			Flow rate	(ox, fuel)
			Bleed rate	(ox, fuel)
			Boil-off rate	(ox, fuel)
			Inlet Temp	(ox, fuel)
			NPSP	(ox, fuel)
			Ullage press	(ox, fuel)
			Engine checkout	
			Engine weight	
			Functional checks	
			I/F duct size	
			Allowable leakage	
			Engine removal/installation	
			Component removal/installation	
			I/F checks	
			Leak checks	
Vehicle Core	Structures	-	Core size	
			Core dry weight	
			Booster quantity	
			Cargo weight	
			Cargo size	
			Booster weight	
			Booster size	
			Thrust loads	
			Safety factor	
			Bending moment	
			Separation loads	
			Acceleration loads	
			Booster attachment	

Table 6. Example Critical Subsystem Characteristics (Continued)

System	Subsystem	-	Critical Characteristics	
			P/L attachment	
			Tank size	
			Skin temp	
			I/F checks	
			Booster mate	
			Cargo mate	
Launch Processing	Propellants	-	Propellant volume	(ox, fuel)
			Loading rate	(ox, fuel)
			Load accuracy	
			Off-load rate	(ox, fuel)
			Hold time	
			Childown time	(ox, fuel)
			I/F temp	(ox, fuel)
			I/F press	(ox, fuel)
			Bleed flow	(ox, fuel)
			I/F fittings	(ox, fuel)
			Allowable leakage	
			Pressurization & purge	
			Functional checks	
			Component removal/installation	
			I/F checks	
			Leaks checks	
Launch Processing	Handling	-	Attach fitting size	
			Attach fitting quantity	
			Fitting torque	
			Handling loads	
			Mating Tolerance	
			Attach loads/preloads	
			Proof/load checks	
			LV assembly	
			Positioning tolerance	
			Functional checks	

explore the QFD process, little teamwork was employed in preparing this chart, and the relationships established were not fully rationalized. This will be left for the next phase of the research.

The technical importance of each subsystem characteristic was then calculated using the tentative relationship values along with the relative importance ratings of each design requirement which were carried over from the Product Planning Matrix. After completing these calculations, the preliminary Subsystem Deployment Matrix was developed (Figure 6).

3.4 PROCESS PLANNING MATRIX

The purpose of the previous Part (Subsystem) Deployment phase was to provide meaningful inputs to the next planning phase by performing appropriate, objective design analysis. The purpose of the Process Planning Phase is to determine the best process/design combination by performing trade studies of alternatives, determining the critical process parameters, establishing the associated critical process parameter target values, and then identifying those items which should have further development based on their relative importance.

Early in the planning stages of this QFD application project, the ability to define a meaningful Process Planning Phase appeared crucial to establishing the viability of the method. Since this application was much more complex than a typical QFD project and the ALS program was only conceptual at this point, a higher functional level was necessary than that found in a usual QFD application. As a result, neither the inputs to nor outputs from the Process Planning Phase were intuitively obvious. As noted earlier, this was partly due to the fact that the launch processing operations being analyzed and designed were also a part of the process.

As a first cut, the process elements were defined based on the operating factors outlined in the Product Planning Matrix design requirements. These basic process elements were redefined in this phase as Production Operations, Launch Processing Operations, and Support Operations.

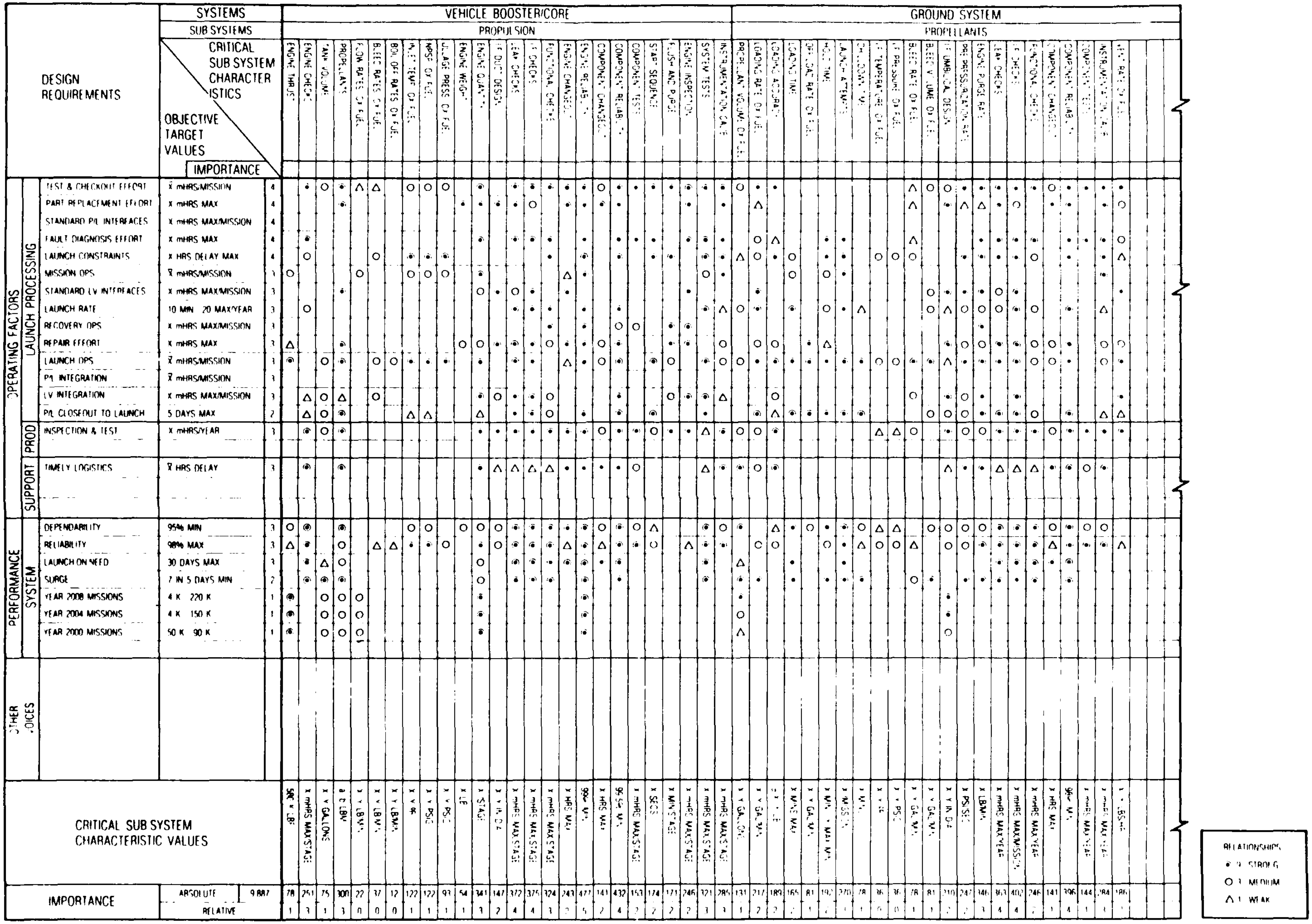

Figure 6. Subsystem Deployment Matrix

These process elements are outlined in Table 7 along with the process subelements. Figures 7 through 9 are flow diagrams of each process element.

Since the principal objective of the Process Planning Phase is determining the best process/design combinations by analyzing alternative concepts, an attempt was made to discover how this could be done in this application. Taking the output of the Subsystem Deployment Phase, two examples were prepared, and the results are discussed in the following paragraphs.

3.4.1 Subsystem Examples

In the previous phase, two subsystem examples were identified for each major system: Propulsion and Structures Subsystems for the Vehicle Core, and Propellants and Handling Subsystems for Launch Processing. For this phase, the subsystems were regrouped according to type; i.e., Process Planning Matrices were prepared which combined the complementary vehicle and launch processing subsystems. Also, in order to better understand the process without getting overly concerned with results (since this is only exploratory), the output from the Subsystem Deployment Matrix was organized into two levels. The first-level matrix consisted of those subsystem characteristics from the previous example which yielded the highest relative importance ratings, and the second-level matrix contained those which were at the next highest level of importance.

The first example of the Process Planning Phase is described in Tables 8 through 10 and Figures 10 and 11. In Table 8, the deployed subsystems were recombined as Propulsion/Propellants. Their resulting critical characteristics, contained in the column representing the highest importance, were then entered together into the Process Planning Matrix as WHATs as shown in Figure 10. These critical characteristics were then related to the basic process element(s) most affected. Based on the requirement noted, the appropriate design/process alternatives can then be identified. An example of the types of subsystem/operation design alternatives which were identified for the Propulsion/Propellants combination is shown in Table 9. These alternatives

Table 7. Basic Process Elements

Launch Processing Operations	Production Operations
Test & checkout	Manufacturing
Integration	Fabrication
Repair	Subassembly
Part replacemet	Final assembly
Fault diagnosis	Paint & insulate
Hazardous Operations	Inspection & test
Launch Operations	Fault diagnosis
Mission Operations	Part replacement
Recovery	Repair
	Support Operations
	Maintenance
	Logistics supply
	Range Operations

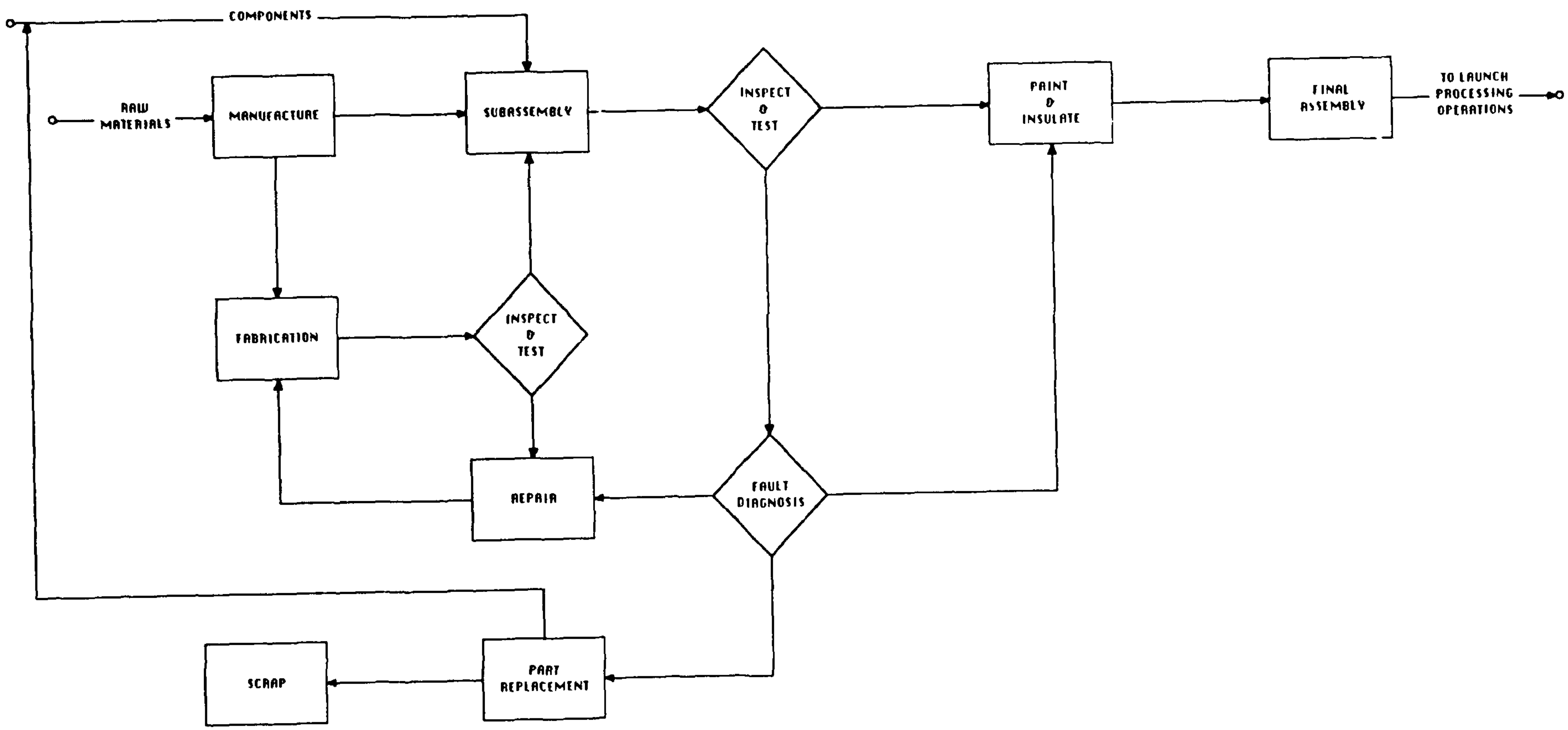

Figure 7. Production Operations Flow Diagram

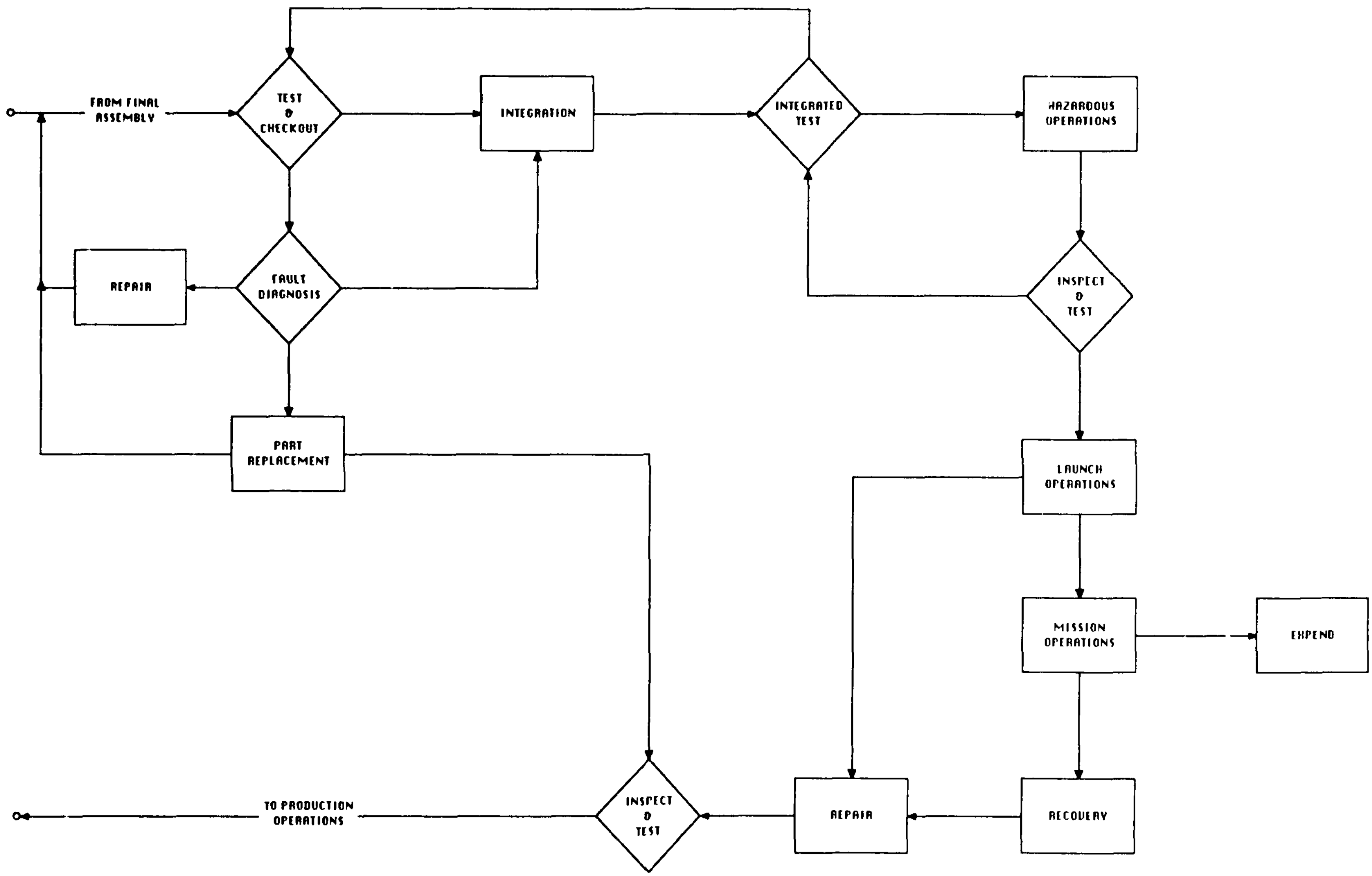

Figure 8. Launch Processing Operations Flow Diagram

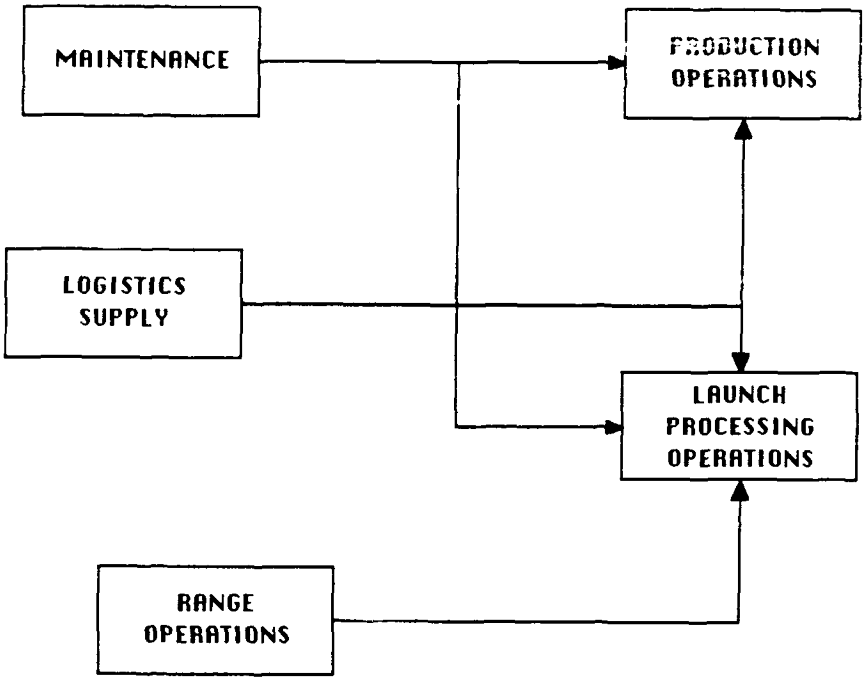

Figure 9. Support Operations Flow Diagram

Table 8. Propulsion and Propellants Subsystems Critical Characteristics

System	Highest Importance	Next Highest Importance
Vehicle Core	I/F checks	Component changeout
	Leak checks	Engine changeout
	Engine quantity	Functional checks
	Allowable leakage	Engine checkout
	Propellants	
Launch Processing	Allowable leakage	Component changeout
	I/F checks	Functional checks
	Leak checks	Pressurization & purge
		I/F fittings
		Hold time
		Load accuracy

Table 9. Alternative Analysis of Propulsion/Propellants Subsystems (Highest Importance)

System	Subsystem Characteristic Being Controlled	Basic Process Element	Alternatives
Vehicle Core			Manual Bubble soap
	Leak checks	Test & checkout	Manual Detector
			Remote Detector
		Fault diagnosis	Automatic Detector
	Allowable leakage		none
	I/F Fitting	Assembly	
	I/F checks	Integration	Single engine/element
			Multi engines/element
		Launch OPS	Single feed/fill/purge/press
	I/F connection		Multi feed/fill/purge/press
		Inspection & test	Booster crossover
			Manual inspection & mate & test
			Simulator prechecks & auto mate & test
			Auto prechecks & mate & test
	Propellants	Logistics supply & Hazardous OPS & Launch OPS	X lb cryos X lb hypers X lb HC x,y,z lb mixed
	Engine quantity	Manufacture & final assy	single engine 2 4 6 8
Launch Processing	Leak checks & Allowable Leakage	Test & checkout & Fault diagnosis	Manual bubble soap Manual detector Remote detector Remote sensor Automatic detector None
	I/F checks	Launch OPS & Fault diagnosis	Manual insp/mate/test Simulator pretest/manual mate Simulator pretest/auto & test mate Auto prechecks/mate & test

Table 10. Alternative Analysis of Propulsion/Propellants Subsystems (Next Highest Importance)

System	Subsystem Characteristic Being Controlled	Basic Process Element	Alternatives
Vehicle Core	Component changeout	Part replacement	Flanged/bolted Clamped Welded/bronzed Threaded
	Engine changeout	Part replacement & Final Assy	Manual align & bolted Manual align & clamp Auto align & manual attach Auto align & attach
	Functional checks	Test & checkout & Fault diagnosis	Manual engineering test & analysis Semi-auto test & eng'g analysis Fully-autotested & eng'g analysis Manual test & auto analysis Fully-auto test & analysis
	Engine checks	Test & checkout & integration	Manual engineering test & analysis Semi-auto test & eng'g analysis Fully-autotested & eng'g analysis Manual test & auto analysis Fully-auto test & analysis
Launch Processing	Component changeout	Part replacement	Flanged/bolted Clamped Welded/brazed Threaded
	Functional checks	Test & checkout & Fault diagnosis	Manual engineering test & analysis Semi-auto test & eng'g analysis Fully-auto test & eng'g analysis Manual test & auto analysis Fully-auto test & analysis
	I/F fittings		Fly-away umbilicals fittings Explosive separation fittings Break-away umibilcal fittings Static loaded fittings Pressure actuated fittings
	I/F Connnection	Integration & Launch OPS	Manual connect/flanged Manual connect/Q.D. Auto connect/Q.D. Robotic connect
	Press'n & purge	Integration & Launch OPS	GHe only/auto GHe only/manual GHe & GH2/auto GHe & GN2/manual
	Load accuracy	Launch OPS	+1-10 gal +1-100 gal +1-1000 gal
	Hold time	Launch OPS	1/4 hr, 1 hr, 4 hr, 12 hr, 24 hr

MASTER FLOW DIAGRAM	
RELATIONSHIPS: ● STRONG, O MEDIUM, Δ SMALL	PROCESS ELEMENTS ⇨ / CRITICAL PROCESS PARAMETERS ⇨

		CRITICAL CHARACTERISTICS	CRITICAL CHARACTERISTIC VALUES	IMPORTANCE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
VEHICLE CORE	PROPULSION																										
		Leak checks	X mhrs MAX/mission																								
		Allowable leakage	X, Yscfm																								
		Engine quantity	X MIN, Y MAX																								
		I/F checks	X mhrs MAX/mission																								
		Propellant	X lb, Y lb																								
GROUND	GROUND PROPELLANTS																										
		Leak checks	X mhrs MAX/mission																								
		Allowable leakage	X, Y scfm																								
		I/F checks	X mhrs MAX/mission																								
PROCESS CAPABILITY																											
CRITICAL PROCESS PARAMETER VALUES																											
IMPORTANCE	ABSOLUTE																										
	RELATIVE																										

AMERICAN SUPPLIER INSTITUTE, INC., MODIFIED FORMAT

Figure 10. Process Planning Matrix Propulsion/Propellants (Highest Importance)

MASTER FLOW DIAGRAM																											
RELATIONSHIPS: • STRONG, O MEDIUM, Δ SMALL		PROCESS ELEMENTS ⇨																									
		CRITICAL PROCESS PARAMETERS ⇨																									
		CRITICAL CHARACTERISTICS	CRITICAL CHARACTERISTIC VALUES	IMPORTANCE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
VEHICLE CORE	PROPULSION																										
		Componen' R&I	X hrs MAX																								
		Engine R&I	X hrs MAX																								
		Functional checks	X mhrs MAX/mission																								
		Engine Checks	X mhrs MAX/mission																								
GROUND	GROUND PROPELLANTS																										
		Component R&I	X hrs MAX																								
		Functional checks	X hrs MAX/mission																								
		I/F fittings	X hrs MAX/mission																								
		Press & purge	X lb/min																								
		Load accuracy	+/- X gal																								
		Hold time	X hrs MIN																								
			X hrs MAX																								
PROCESS CAPABILITY																											
CRITICAL PROCESS PARAMETER VALUES																											
IMPORTANCE		ABSOLUTE																									
		RELATIVE																									

AMERICAN SUPPLIER INSTITUTE, INC., MODIFIED FORMAT

Figure 11. Process Planning Matrix Propulsion/Propellants (Next Highest Importance)

would be traded against the critical parameters which are used as criteria for each system and which are traceable back to the original customer requirement by way of the operations design requirements. The Propulsion/Propellants subsystem example was continued into the next highest importance level of subsystem characteristics in a similar manner to the most important characteristics with the results shown in Figure 11 and Table 10.

The identical procedure was also used on the Structures/Handling subsystem combination. Table 11 lists the highest and next highest characteristics in level of importance, and Tables 12 and 13 and Figures 12 and 13 list the design/operations alternatives.

While preparing this preliminary example, several items were found which needed correction. For example, several critical characteristics were carried over to the Process Planning Matrix which did not satisfy the concept of a subsystem/operations combination. In using this process, trade studies of alternative concepts were identified which should be performed as part of the Subsystem Deployment Phase rather than the Process Planning Phase. A procedure for identifying these will be added in the next iteration. Examples included engine quantity, safety factor, and core and booster size and weight. Another finding was that certain other items, such as interface fitting design, influenced both Production Operations and Launch Processing Operations. Therefore, it was concluded that for this application, the Process Planning output should logically split into these two process element options for further analysis. Since Support Operations does not stand alone, no separate planning process was identified for it. The resultant Process Planning Matrix which was developed using this methodology is shown in Figure 14 for the propulsion/propellants example.

Table 11. Structures and Handling Subsystems Critical Characteristics

System	Highest Importance	Next Highest Importance
Vehicle Core	Safety factor	Booster attachments
	P/L attachments	Separation load
	I/F checks	Skin temp
	Cargo mate	Booster mate
	Booster quantity	Core size
		Cargo size
		Cargo weight
Launch Processing	Attach fitting quantity	Fitting torque
	Mating tolerance	Attach fitting size
	Proof/load checks	Attach loads
	LV assembly	Positioning tolerance
	Functional checks	

Table 12. Alternative Analysis for Structures/Handling Subsystems (Highest Importance)

System	Subsystem Characteristic Being Controlled	Basic Process Element	Alternatives
Vehicle Core	Safety factor	Maintenance	1.1 : 1 1.25 : 1 1.6 : 1 2 : 1
	I/F Connection & Checks I/F Fitting	Integration & Manufacture & Inspection & Test	Single element Multi element Single feed/fitting/cable Multi fee/fitting/cable Booster/core crossovers
	P/L attachments	Integration & Launch OPS	Separation pin Separation flange Separation clamp Explosive fitting Service passthroughs Bypass service
	Booster quantity	Integration Test & checkout Print & insulate	2 6 12
	Cargo mate	Integration	Manual align & inspection & mate Manual align & inspection & auto mate Manual align & auto inspection & mate Auto align & manual inspection & mate Auro align & inspection & manual mate Auto align & inspection & mate
Launch Processing	Attach fitting/ quantity	Integration	1 per element 2 per element 4 per element 8 per element
	Mating tolerance	Integration	+1 - .001 in +1 - .01 in +1 - .1 in
	LV Assembly	Integration	Manual align & inspection & mate Manual align & inspection & auto mate Manual align & auto inspection & mate Auto align & manual inspection & mate
	Functional Checks	Test & checkout & Fault diagnosis	Manual test & verify Manual test & auto verify Auto test & verify
	Proof/load checks	Test & checkout	Semi-annual proof & load test Annual proof & semi-manual load test Lead before use only test Semi-annual proof & no-load test Annual proof & no-load test

Table 13. Alternative Analysis for Structures/Handling Subsystems (Next Highest Importance)

System	Subsystem Characteristic Being Controlled	Basic Process Element	Alternatives
Vehicle Core	Booster Attachment	Integration	Separation pin Separation flange Separation clamp Explosive fitting Thru services Bypass services
	Separation loads	Integration	Belleville spring Coil spring Thrusters Gravity
	Booster mate	Integration	Manual align & inspection and mate Manual align & inspection & auto mate Manual align & auto-inspection & mate Auto align & manual inspection & mate
	Skin temp	Paint & Insulate & Integration & Launch OPs	Foam tile insulation S/O foam insulation Ablative insulation Blanket insulation Mixed insulation No insulation
Launch Proccessing	Attach fitting size	Integration	1 x 3 in 1 x 6 in 2x12 in 3 x 12 in
	Fitting torque	Integration	10 ft-lb 100 ft-lb 1000 ft-lb
	Attach loads	Integration	+1 - 1/4 lb +1 - 1 lb +1 - 4 lb +1 - 10 lb
	Positioning tolerance	Integration	+1 - .01 in +1 - 1 in +1 - 1/4 in +1 - 1 in

MASTER FLOW DIAGRAM																											
RELATIONSHIPS: • STRONG, O MEDIUM, Δ SMALL		PROCESS ELEMENTS ⇨																									
		CRITICAL PROCESS PARAMETERS ⇨																									
		CRITICAL CHARACTERISTICS	CRITICAL CHARACTERISTIC VALUES	IMPORTANCE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
VEHICLE CORE	STRUCTURES	Safety factor	X:1 yield																								
		I./F checks	X mhrs MAX/mission																								
		Booster quantity	X MIN, Y MAX																								
		P/L attachments	X fittings																								
		Cargo mate	X mhrs MAX/mission																								
GROUND	HANDLING	Attach fitting qty	X couplings																								
		Mating tolerance	+/- X in																								
		LV assembly	X days MAX/mission																								
		Functional checks	X hrs MAX/mission																								
		Proof/load checks	X hrs MAX/mission																								
PROCESS CAPABILITY																											
CRITICAL PROCESS PARAMETER VALUES																											
IMPORTANCE		ABSOLUTE																									
		RELATIVE																									

AMERICAN SUPPLIER INSTITUTE, INC., MODIFIED FORMAT

Figure 12. Process Planning Matrix for Structures/Handling Subsystems (Highest Importance)

MASTER FLOW DIAGRAM	
RELATIONSHIPS:	PROCESS ELEMENTS ⇨
• STRONG	
O MEDIUM	CRITICAL PROCESS PARAMETERS ⇨
Δ SMALL	

		CRITICAL CHARACTERISTICS	CRITICAL CHARACTERISTIC VALUES	IMPORTANCE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
VEHICLE CORE	STRUCTURES	Booster attchmt	X fittings																								
		Separation loads	X lb, Y ft-lbs																								
		Booster mate	X mhrs MAX/mission																								
		Core size	X ft by Y ft																								
		Cargo size	X lb, Y lb																								
		Cargo weight	X lb MIN, Y lb MAX																								
		Skin temp	X°R MIN, Y°R MAX																								
GROUND	HANDLING	Attach fitting size	X in by Y in																								
		Fitting torque	X ft-lb																								
		Attach loads	+/- X lb																								
		Positioning toler-ance	+/- X in																								
PROCESS CAPABILITY																											
CRITICAL PROCESS PARAMETER VALUES																											
IMPORTANCE		ABSOLUTE																									
		RELATIVE																									

AMERICAN SUPPLIER INSTITUTE, INC., MODIFIED FORMAT

Figure 13. Process Planning Matrix for Structures/Handling Subsystems (Next Highest Importance)

RELATIONSHIPS

◉ 9 STRONG

○ 3 MEDIUM

△ 1 WEAK

Master Flow Diagram: Assembly / Test / Integration / Launch Processing	Process Elements	VEHICLE BOOSTER/CORE – PROPULSION: ENGINE RELIABILITY (99% MIN) [5]	COMPONENT RELIABILITY (99.5% MIN) [4]	I/F CHECKS (X mHRS MAX/STAGE) [4]	LEAK CHECKS (X mHRS MAX/STAGE) [4]	ENGINE QUANTITY (X /STAGE) [3]	FUNCTIONAL CHECKS (X mHRS MAX/STAGE) [3]	SYSTEM TESTS (X mHRS MAX/STAGE) [3]	PROPELLANTS (a. b LBM) [3]	INSTRUMENTATION CALIB (X mHRS MAX/STAGE) [3]	ENGINE CHECKS (X mHRS MAX/STAGE) [3]	GROUND – PROPELLANTS: I/F CHECKS (X mHRS MAX/MISSION) [4]	COMPONENT RELIABILITY (98% MIN) [4]	LEAK CHECKS (X mHRS MAX/MISSION) [4]	ENGINE PURGE (X LB/MIN) [3]	INSTRUMENTATION CALIB (X mHRS MAX/YEAR) [3]	LAUNCH ATTEMPTS (X /MISSON) [3]	PROCESS CAPABILITY	CRITICAL PROCESS PARAMETER VALUES	IMPORTANCE ABSOLUTE (3,119)	IMPORTANCE RELATIVE
PRODUCTION OPS – ASSEMBLY	TANK INSPECTION			△	○				◉									✓	STANDARD PROC	43	1
	THRUST STRUCTURE INSTLN			○		◉													ALIGNMENT TOOL	39	1
	PIPING INSTALLATION			△	◉	◉			○										AUTO BRAZE/WELD	76	2
	COMPONENT INSTALLATION		◉		◉	◉	◉	○	○									✓	STANDARD PROC	144	5
	CABLE INSTALLATION			◉		◉		◉		◉									AUTO SPOOLING	117	4
	ENGINE INSTALLATION	◉		◉	◉	◉	◉	○	○		○								ALIGNMENT JIG	198	6
PRODUCTION OPS – INSPECTION & TEST	TANK LEAK TEST				◉													✓	DECAY TEST	36	1
	PRESSURE SYS LEAK TEST				◉														MASS SPEC/REMATE	36	1
	PURGE SYS LEAK TEST				◉														MASS SPEC/REMATE	36	1
	FILL SYSTEM LEAK TEST				◉	◉													VACUUM/MASS SPEC	63	2
	VENT INSPECTION			○	○													✓	STANDARD PROC	24	1
	BLEED INSPECTION			○	○	◉												✓	STANDARD PROC	51	2
	VALVE RESPONSE		◉				◉	◉		○									HMS AUTO CYCLE	99	3
	ELECTRICAL INTEGRITY		◉	○		◉	○	◉		○									AUTO CONT/ISO	120	4
	ENGINE INSPECTION	◉				◉	◉	◉	○		◉							✓	INTEGRITY CHECKS	162	5
	SENSOR INSTALLATION	◉	◉			◉	◉	◉		◉								✓	STANDARD PROC	189	6
	CALIBRATION									◉									AUTO CAL	27	1
LAUNCH PROCESSING – INTEGRATION	STAGE TRANSPORT																		X HRS		
	STAGE MATE			○															CRANE MATE	12	0
	UMBILICAL MATE			○															AUTO ROBOTIC	12	0
	I/F CHECKS			◉															AUTO INTEGRITY	36	1
	SYSTEM TIMING		◉				◉	◉											HMS AUTO SEQ	90	3
	ENGINE TIMING	◉				◉					◉								AUTO SEQUENCE	99	3
	POWER ON		◉			◉		◉											POWER ON PROC	90	3
	HYDRAULIC POWER ON		◉			◉		◉											AUTO SEQUENCE	90	3
	SENSOR CHECKS	◉	◉			◉	◉	◉		◉									HMS AUTO CAL	189	6
	SEPARATION INSTALLATION																	✓	STANDARD PROC		
	SYSTEM LEAK CHECKS				◉														AUTO MASS SPEC	36	1
	ALL SYSTEMS TEST	◉	◉			◉	◉	◉		◉	◉								LCC CONTROL	216	7
	P/L MATE																		STANDARD PROC		
	SIM FLIGHT																		AUTO LCC		
LAUNCH OPS	VEHICLE TRANSPORT																		X HRS		
	GROUND SYS LEAK CHECKS													◉					AUTO SCAN	36	1
	GROUND SYS VALVE CYCLE												◉						AUTO RESPONSE	36	1
	I/F CONNECTIONS											○							AUTO SEMI-ROBOTIC	12	0
	I/F CHECKS											◉							AUTO INTEGRITY	36	1
	ORDNANCE INSTALLATION																		X HRS		
	RANGE TESTS			◉								◉							LCC COMM	72	2
	MISSION OPS CHECKS																		LCC/MCC COMM		
	CONTROL/RESPONSE TEST																		HMS AUTO SEQ		
	PURGES ON																		AUTO CYCLE		
	COMMODITY SERVICING																		X HRS		
	PROPELLANT LOAD PREPS												◉		◉	◉			SEMI AUTO CYCLE	90	3
	PROPELLANT LOADING	○	○		◉	○	○	◉	◉				○	◉	○				AUTO LOAD PROC	192	6
	COUNTDOWN	◉	◉			◉											◉		COUNTDOWN PROC	135	4
	SAFING								◉				◉						AUTO SAFE/ABORT	63	2
RECOVERY OPS	RETRIEVAL																		X HRS		
	SAFING								◉										AUTO SAFE	27	1
	FLUSH & PURGE					◉									◉				AUTO SEQ	54	2
	DISASSEMBLY																	✓	STANDARD PROC		
	REFURBISHMENT																	✓	STANDARD PROC		
	COMPONENT CHECKS		◉															✓	STANDARD PROC	36	1
	HOT FIRE																		SHIP TO VENDOR		

Figure 14. Process Planning Matrix for Propulsion/Propellants Subsystems

4. INITIAL RESULTS

Initial attempts at evaluating the QFD process for application to launch operations yielded many informative and useful findings which will be used to modify the QFD process and also the assumptions made in the previous attempts. These adjustments will then be used in a revised analysis which will give a better test of this procedure against the AFSPACECOM operational requirements. This will eventually be followed by a final examination of the merits of this QFD application.

4.1 QFD PROCESS REFINEMENTS

As a result of the first iteration of this QFD project, the need to systematically redefine the development functions in terms of their application became evident. As outlined in the ASI approach, the four phases of the Quality Function Deployment Process were designed to mesh with the four phases of the product development cycle. These four product development events and their associated management review milestones are shown in Figure 15. Each of the four phases from planning through production are analogous to the four phases in our system development. These analogies are tabulated as follows:

	PRODUCT DEVELOPMENT CYCLE		SYSTEM DEVELOPMENT CYCLE	
PHASES	EVENTS	MILESTONES	EVENTS	MILESTONES
I	Product Planning	Global Product Definition	Concept Definition	0
II	Product Design	Prototype Evaluation	Demonstration/ Validation	I
III	Manufacturing Process Engineering	Pilot Evaluation	Full-Scale Development	II
IV	Production	Production Start	Production	III

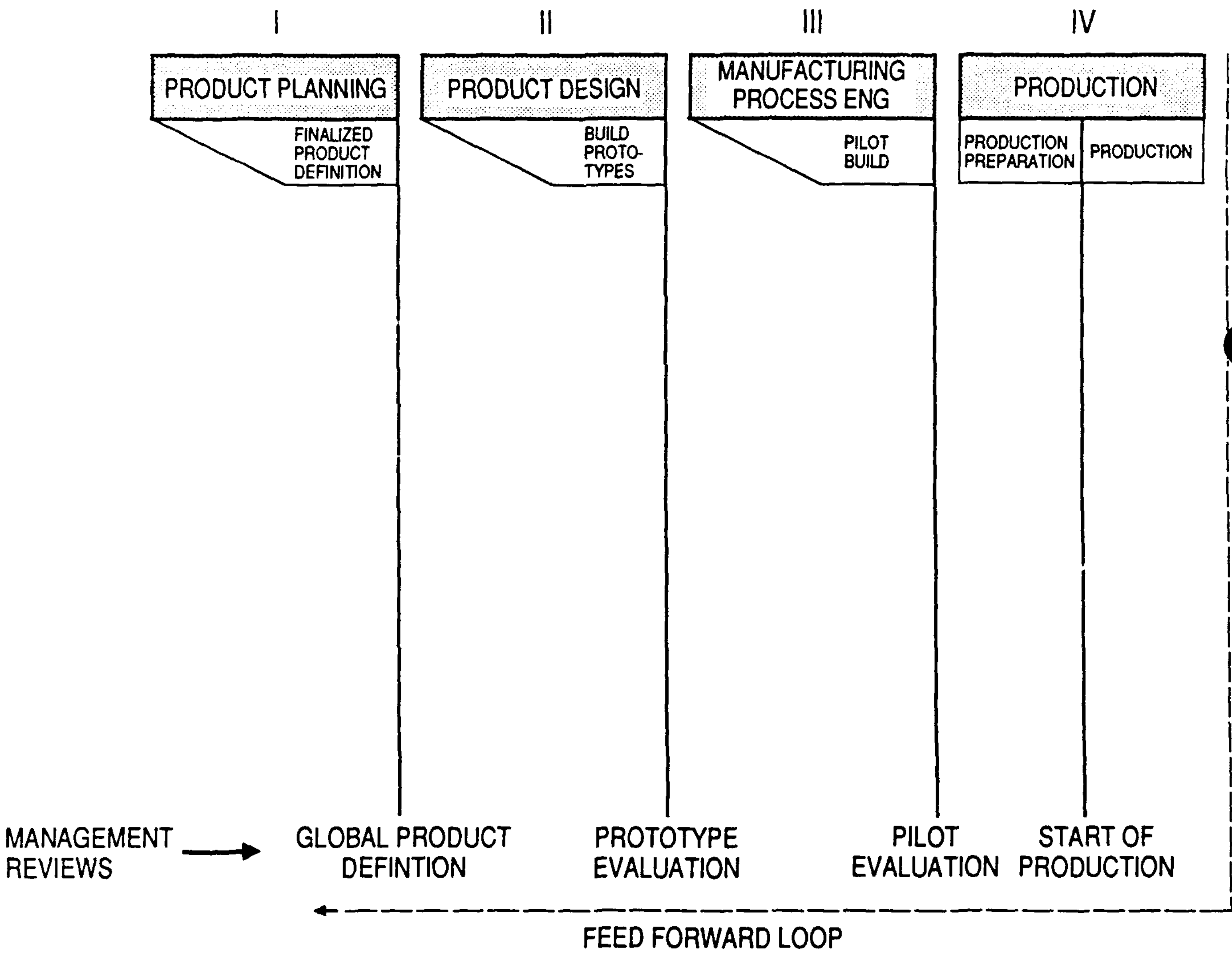

Figure 15. Major Phases of the Product Development Cycle

The relationships between these planning functions and the refinements defined in our analogy are as shown in Figure 16. The relative phasing of the QFD and the development processes for both the product/system analogies are also shown in Figure 16.

However, for our application, an additional phase can be identified which is associated with system operation. This phase (which is the objective of our QFD example) constitutes an additional end event in the engineering development cycle beyond production. The analogy comparison between the product and system development cycles is shown in Figure 17, which is an overlay of the two cycles.

In the QFD process, this extra dimension adds an additional feature to the process. In completing the analogy between product and system development, the QFD process was evaluated and refined as follows:

PRODUCT QFD	SYSTEM QFD
Product Planning	System Planning
Part Deployment	Subsystem Deployment
Process Planning	Process Planning
Production Planning	Production Planning Operations Planning

A prototype Operations Planning Matrix was generated in order to demonstrate the types of procedure-level information which would be generated through this modified QFD process. Figure 18 is an example of this type of matrix which gives test criteria, operational evaluations, prerequisites, planning/quality requirements, procedure used, and support requirements. All of this information is derivable from and directly correlatable to the original System Planning Matrix.

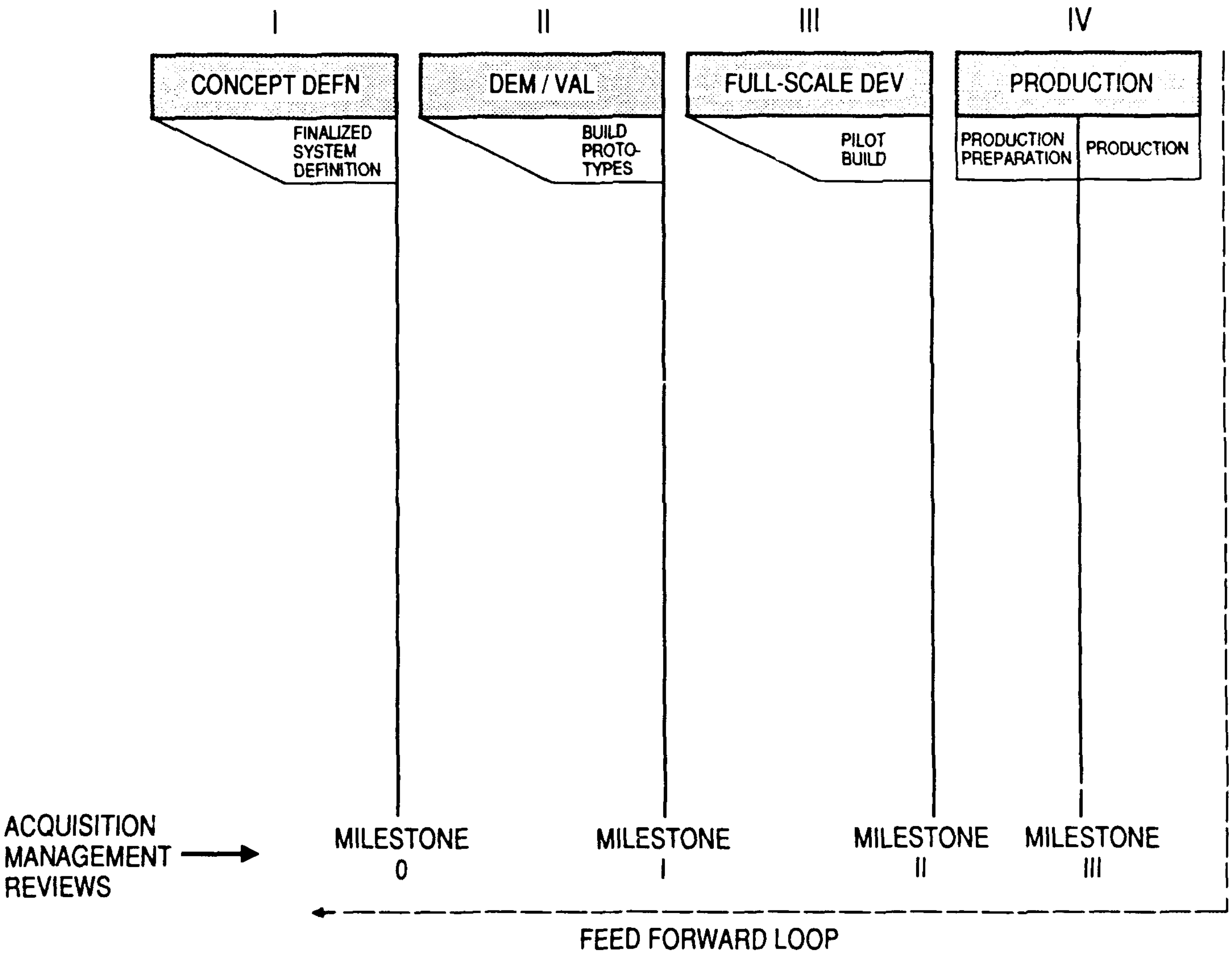

Figure 16. Major Phases of the System Development Cycle

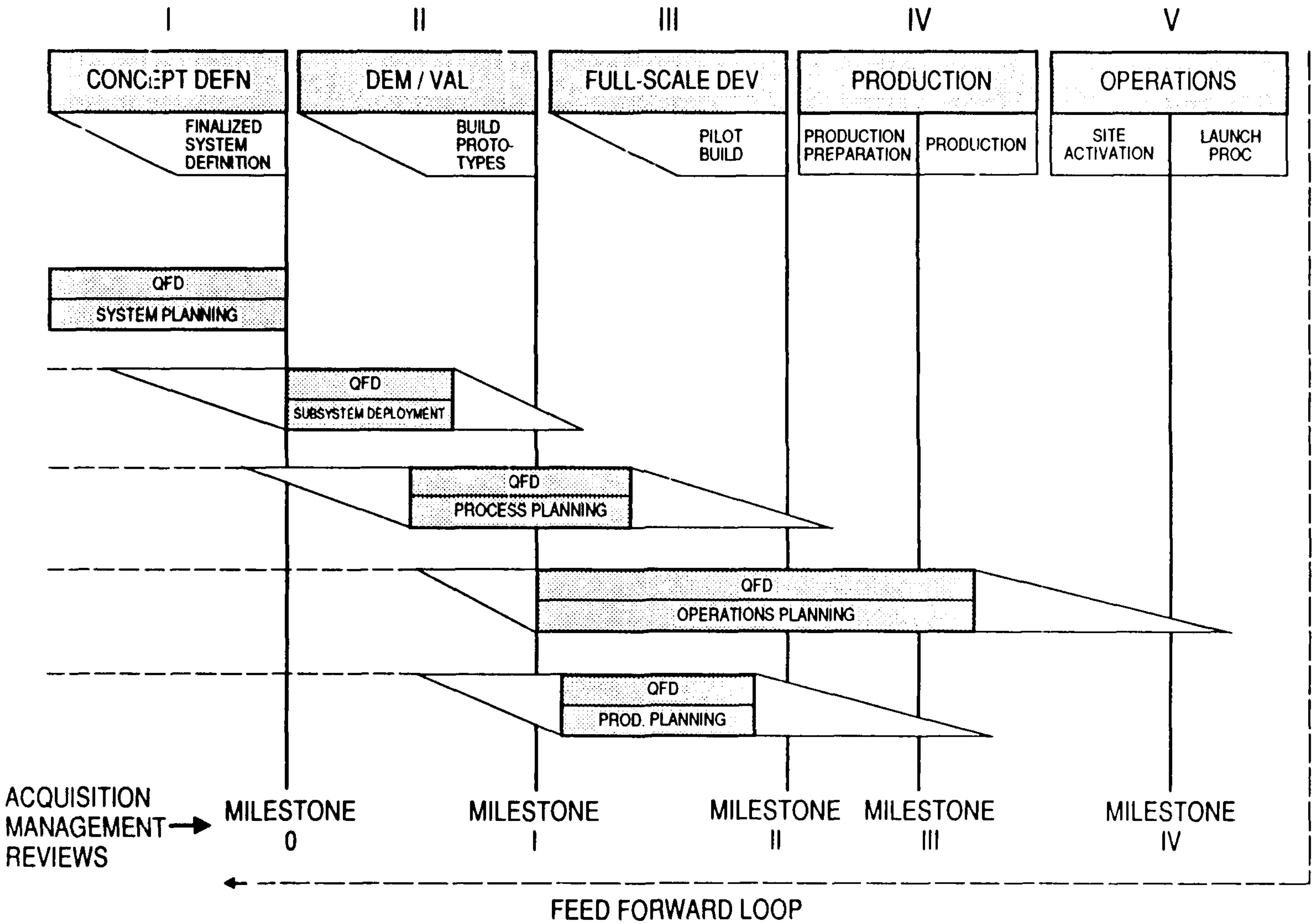

Figure 17. Overlaying QFD on the System Development Cycle

Process	Elements	Critical Process Parameters	Critical Process Parameter Values	Process Capability	Importance	Operation Evaluation: Difficulty	Frequency	Severity	Ability to Detect	Total	Operating Requirements: Prerequisites	Specification	Planning Requirements: Quality Control Chart	Preventive Maintenance	Mistake Proofing	Training Requirements	Operation Information: Procedure	Direct	Indirect Labor	Support	Time Limited	Remarks
PRODUCTION OPS	ASSY	COMPONENT INSTALLATION	STANDARD PROCEDURE	✓	5	2	3	1	1	6		MANUAL			✓	✓	JI X	X	Y			
		CABLE INSTALLATION	AUTO SPOOLING		4	3	2	1	2	12				✓		✓	JI Y	X	Y			
		ENGINE INSTALLATION	ALIGNMENT JIG		6	3	1	3	2	18	JI q	±0.1 m		✓	✓	✓	JI Z	X	Y			
	INSP & TEST	ELECTRICAL INTEGRITY	AUTO CONTINUITY/ISO		4	1	1	1	2	2	JI y	0.1 Ω	✓				TP a	X				
		VALVE RESPONSE	HMS AUTO CYCLE		3	1	2	1	1	2	TP q	ON OFF		✓			TP b	X		Z		
		ENGINE INSPECTION	INTEGRITY CHECKS	✓	5	1	1	2	1	2	JI z		✓				TP c	X	Y			
		SENSOR INSTALLATION	STANDARD PROCEDURE	✓	6	2	3	1	2	12		MANUAL				✓	JI d	X	Y			
LAUNCH PROCESSING	INTEGRATION	SYSTEM TIMING	HMS AUTO SEQUENCE		3	2	2	1	2	8	OMI X	±0.25 SECS		✓			OMI a	X		Z		
		ENGINE TIMING	AUTO SEQUENCE		3	2	1	3	2	12	OMI Y	1.5 SEC					OMI b	X				
		POWER ON	POWER ON PROCEDURE		3	1	2	2	2	8	OMI Z	28 ± 2 VDC					OMI c	X				
		HYDRAULIC POWER ON	AUTO SEQUENCE		3	3	2	2	1	12	OMI C	3200 ± 100 psi					OMI d	X				
		SENSOR CHECKS	HMS AUTO CAL		6	3	2	2	1	12	OMI C	±0.5%	✓	✓			OMI e	X		Z		
		ALL SYSTEMS TEST	LCC CONTROL		7	2	1	3	2	12	OMI's a Z	S/W VERIFY					I OMI a	X	Y	Z		
	LAUNCH OPS	PROPELLANT LOAD PREPS	SEMI AUTO CYCLE		3	2	1	2	1	4		S/W VERIFY	✓				G OMI a	X				
		PROPELLANT LOADING	AUTO LOAD PROCEDURE		6	3	1	3	2	18	GOMI a	100 ± 0.5%					I OMI b	X			4 HRS	
		COUNTDOWN	COUNTDOWN PROCEDURE		4	3	1	3	3	27	IOMI ab	12 ± [illegible] HRS					COM	X	Y	Z	24 HRS	

Figure 18. Operations Planning Matrix

4.2 SAMPLE POPULATION

The population consists of personnel at both the Space System Division JPO and Space Command.

4.3 PERSONAL INTERVIEWS

In addition to the information provided by the written questionnaire, discussions were held via telephone and group sessions with key personnel to corroborate the written version. These discussions provided additional insight into the issues and concerns facing ALS. Important advantages derived from this approach were the high quality of the data garnered as well as the highest response rate of any survey technique. Further follow-up discussions and telephone calls were conducted to provide additional insight and data.

4.4 FIELD RESEARCH

After the literature review, this project tested its objectives by means of a questionnaire developed from the SORD requirements. The questionnaires, with a cover letter and instructions intended to ensure a meaningful response, were mailed to individuals in positions of authority or influence. The letter and instructions explained the purpose of the research, as well as its focus. Three primary areas were emphasized: Customer (User) Requirements, Design Requirements, and System/Subsystem Characteristics.

5. RECOMMENDATIONS

Ideas for following up on this research task are many and varied, but the effort will be limited by the availability and dedication of resources and the degree of management support. There is no question that further study will be difficult, time-consuming, and iterative.

In order to complete this investigation, two paths should be pursued: continuation of the general new project application represented by the Advanced Launch System Program, and a detailed study which addresses a particular problem area. Specific recommendations are summarized as follows:

- Continue the ALS customer research and perform a true survey of greater depth and breadth.
- Evaluate more advanced QFD techniques and determine whether an appropriate QFD methodology exists for this application.
- Survey existing launch programs and identify a specific operations problem area.
- Obtain necessary supporting data.
- Perform a QFD pilot project applying the defined methodology to the identified problem using appropriate data.
- Critique both the methodology and application for areas of improvement.
- Document results and implement findings as appropriate.

6. REFERENCES AND BIBLIOGRAPHY

6.1 REFERENCES

1. W. Edwards Deming, Out of the Crisis, MIT CAES, (1986).

2. "Quality Function Deployment Implementation Manual," Version 3.0, American Supplier Institute, Dearborn, Michigan (1989).

3. S. T. Johnson, "RSG Quality Function Deployment Pilot Project."

4. J. B. ReVelle, The New Quality Technology, Hughes Aircraft Co., Los Angeles, California (1988).

5. AF SPACECOM, ALS System Operational Requirements Document (1989).

6. AF/NASA, ALS Systems Requirements Document (1989).

7. Portanova, P. L., and E. J. Tomei, "Applying Quality Function Deployment to Launch Operations," Presented at AIAA/ADPA NSIA First National Total Quality Management Symposium, Denver, CO, 1-3 November 1989.

6.2 BIBLIOGRAPHY

Drucker, Peter F., Management: Tasks, Responsibilities, Practices Harper and Row (1974)

Hauser, John R., and Don Clausing, "The House of Quality," Harvard Business Review, May-June 1988, pages 63-73.

King, Bob, Better Designs in Half the Time, Implementing QFD in America, GOAL/QPC (1987).

Walton, Mary, The Deming Management Way, Perigee Books (1986).

APPENDIX A. QFD CUSTOMER SURVEY FOR LAUNCH OPERATIONS

89-3516-235-PLP

24 August 1989

Subject: Quality Function Deployment Research Customer Survey

To:

1. A great deal has been written and said during the past few years about the use of Quality Function Deployment (QFD) in product development. However, applying QFD to launch operations has never been attempted. It is certain that QFD has a future, but it is becoming more and more important to appraise that future realistically so workable plans and requirements can be translated into launch systems which satisfy the customer.

2. We are exploring the use of QFD methodology to verify AF SPACECOM operational requirements. The merits as well as the level of difficulty of implementing the QFD process will be presented.

3. Enclosed is the Research Customer Survey directed to this objective. We would appreciate it if you will personally take the time (30 minutes) to respond. The validity of this research depends on the response of people like yourself.

4. The specific information which you provide in response to this survey will be treated strictly as confidential. Preliminary analytical results will be published and presented at the AIAA/ADPA/NSIA First National Total Quality Management Symposium, 1-3 November 1989, Denver, Colorado.

5. We want to thank you in advance for your cooperation and assistance in this research study.

THE AEROSPACE CORPORATION

P. L. Portanova, Director
Operations Directorate
Space Transportation Development Directorate

THE AEROSPACE CORPORATION

E. J. Tomei, Director
Advance Programs & Studies
Western Test Range

PLP:fd
Enclosures
cc:

INSTRUCTIONS TO THE RESEARCH CUSTOMER SURVEY

The following questions are part of a survey being conducted as inputs to a study being performed of QFD methodology relative to Launch Operations. Preliminary results are planned to be presented at the AIAA/ADPA/NSIA First National Total Quality Management Symposium, 1-3 November 1989, Denver, Colorado. The title of our paper is "Applying Quality Function Deployment to Launch Operations," and we are performing research relative to AFSPACECOM operational requirements and the Advanced Launch System (ALS). The research at this phase focused on:

a) Customer (User) Requirements
b) Design Requirements
c) System/Subsystem Characteristics

Participation, through your response to this questionnaire, is very important to our research effort. Your responses are strictly confidential, and complete anonymity is maintained for all personnel and companies who participate.

The attached Research Customer Survey lists our preliminary assessment of customer requirements expressed in QFD format. Please rate these requirements in terms of importance using a relative scale of 1-10 with 10 being best. Also, in the adjoining columns, please provide your assessments of the capability of the identified existing launch vehicles to satisfy these requirements using a relative scale of 1-5 with 5 being best. Any additional comments or added clarifications can be included in the space provided.

We sincerely appreciate your cooperation and assistance.

P. L. Portanova, Director
Operations Directorate
Space Transportation Development Directorate
Office: (213) 336-1860

E. J. Tomei, Director
Advance Programs & Studies
Western Test Range
Office: (805) 866-9908

The following information is optional:

Name ______________________________

May we contact you? Yes ___ No ___ If Yes, ( ) ____________________
Telephone

Please use the reverse side of this questionnaire for additional comments. We would greatly appreciate any additional insights and sources of data/information on this topic that you could share with us.

RESEARCH CUSTOMER SURVEY

	IMPORTANCE RATING 1-10 (Best)	DELTA	ATLAS	SHUTTLE	ARIANE	TITAN	Comments
		1-5 (Best)					
o REDUCE CURRENT OPS COSTS BY AN ORDER OF MAGNITUDE							
o BE AFFORDABLE							
o STREAMLINE OPERATIONS							
o SIMPLIFY PROCEDURES							
o SIMPLIFIED FAULT IDENTIFICATION							
o STANDARDIZED FAULT IDENTIFICATION							
o USE STANDARD AF TRAINING & PRACTICES							
o OPERATE WITH AF PERSONNEL							
o SIMPLIFIED PARTS REPLACEMENT							
o STANDARDIZED PARTS REPLACEMENT							
o NORMALIZE OPERATIONS							
o JOINT SERVICE USE							
o SUPPORT ALL U.S. PAYLOADS							
o REDUCE WORKLOAD							
o AUTOMATED, USER-FRIENDLY ENVIRONMENT							
o NO SINGLE-POINT FAILURES							
o MORE RELIABLE THAN CURRENT							
o ASSURE ACCESS TO SPACE							

APPENDIX B. QFD COMPETITIVE ASSESSMENT SURVEY FOR LAUNCH OPERATIONS

24 August 1989

Subject: Quality Function Deployment Competitive Assessment Research Survey

To:

1. A great deal has been written and said during the past few years about the use of Quality Function Deployment (QFD) in product development. However, applying QFD to launch operations has never been attempted. It is certain that QFD has a future, but it is becoming more and more important to appraise that future realistically so workable plans and requirements can be translated into launch systems which satisfy the customer.

2. We are exploring the use of QFD methodology to verify AF SPACECOM operational requirements. The merits as well as the level of difficulty of implementing the QFD process will be presented.

3. Enclosed is the Competitive Assessment Research Survey directed to this objective. We would appreciate it if you will personally take the time (30 minutes) to respond. The validity of this research depends on the response of people like yourself.

4. The specific information which you provide in response to this survey will be treated strictly as confidential. Preliminary analytical results will be published and presented at the AIAA/ADPA/NSIA First National Total Quality Management Symposium, 1-3 November 1989, Denver, Colorado.

5. We want to thank you in advance for your cooperation and assistance in this research study.

P. L. Portanova and E. J. Tomei, Jr.
(213) 336-1860
Bldg. D9, Room 4721

PLP:fd
Enclosures

INSTRUCTIONS TO THE COMPETITIVE ASSESSMENT RESEARCH SURVEY

The following questions are part of a survey being conducted as inputs to a study being performed of QFD methodology relative to Launch Operations. Preliminary results are planned to be presented at the AIAA/ADPA/NSIA First National Total Quality Management Symposium, 1-3 November 1989, Denver, Colorado. The title of our paper is "Applying Quality Function Deployment to Launch Operations," and we are performing research relative to AFSPACECOM operational requirements and the Advanced Launch System (ALS). The research at this phase focused on:

a) Customer (User) Requirements
b) Design Requirements
c) System/Subsystem Characteristics

Participation, through your response to this questionnaire, is very important to our research effort. Your responses are strictly confidential and complete anonymity is maintained for all personnel and companies who participate.

The attached Competitive Assessment Research Survey lists our preliminary assessment of design requirements expressed in QFD format. In the adjoining columns, please provide your assessments of the capability of the identified existing launch vehicles to satisfy these requirements using a relative scale of 1-5 with 5 being best. Also, please provide your assessment of the risk to the ALS program to satisfy these requirements on a scale of 1-5, with 5 representing the greatest risk. Any additional comments or added clarifications can be included in the space provided.

We sincerely appreciate your cooperation and assistance.

______________________________	______________________________
P. L. Portanova, Director	E. J. Tomei, Director
Operations Directorate	Advance Programs & Studies
Space Transportation Development Directorate	Western Test Range
Office: (213) 336-1860	Office: (805) 866-9908

The following information is optional:

Name ____

May we contact you? Yes ___ No ___ If Yes, ( ) ____________________
Telephone

Please use the reverse side of this questionnaire for additional comments. We would greatly appreciate any additional insights and sources of data/information on this topic that you could share with us.

A subjective assessment will be required to answer most of the questions, so it is important that you follow your best judgement based on data, information, experience and expert knowledge. We are trying to assess the relative capability of the current launch systems to meet certain ALS design parameters and the relative risk of ALS itself to meet these goals. Although most of the specific parameters are not defined yet, we are proceeding on the basis of relative merit. The process will be refined as more data are obtained. In the assessment column, please read the down arrow as "minimize," the up arrow as "maximize," and the dot as "fixed target value."

RESEARCH QUESTIONNAIRE COMPETITIVE ASSESSMENT

o TARGET o MIN O MAX	Design Requirements (How)	Objective Target Value (How Much)	DELTA	ATLAS	SHUTTLE	ARIANE	TITAN	ALS RISK
			1-5 (Best)					1-5 (Strong)
o	LV integration	X mhrs/max/mission						
o	P/L integration	X mhrs/mission						
o	Launch constraints	X hrs delay max						
O	Standard LV interfaces	X mhrs/max/mission						
O	Standard P/L interfaces	X mhrs max/mission						
o	Fuel/defuel	24 hrs max						
o	Environmental impact	X % delay average						
o	P/L changeout	5 days max						
o	Fault diagnosis effort	X mhrs max						
o	Repair effort	x mhrs max						
o	Part replacement effort	X mhrs max						
o	Test & checkout effort	X mhrs max/mission						
o	Integrated test	X hrs/mission						
o	Launch rate	6 min-10 max/yr						
o	Launch-on-need	30 days max						
o	Surge	7 in 5 days max						
o	Resurge	60 days max						
o	Standdown	3 months max						
o	Recovery	135%						

RESEARCH QUESTIONNAIRE COMPETITIVE ASSESSMENT

o TARGET o MIN 0 MAX	Design Requirements (How)	Objective Target Value (How Much)	DELTA	ATLAS	SHUTTLE	ARIANE	TITAN	ALS RISK
			1-5 (Best)					1-5 (Strong)
0	Identity concealment	100%						
o	P/L closeout-to-launch	5 days max						
o	Window	X hrs min-X hrs max						
o	Hazard clear ops	X hrs max/mission						
o	On-pad maintenance	X mhrs max/mission						
o	Intermed. maintenance	Zero						
o	Pad turnaround	6 days max						
0	Timely logistics	X hrs delay max						
o	Logistics effort	X mhrs/mission						
0	Multi-sourcing	100%						
o	Mission ops effort	X mhrs max/mission						
o	Range support effort	X mhrs max/mission						
o	Year 2000 missions	50K min - 90K max						
o	Year 2004 missions	4K min - 150K max						
o	Year 2008 missions	4K min - 220K max						
0	Availability	90% min						
0	Dependability	95% min						
0	Reliability	98% min						
o	Single-point failures	Zero						
0	Survivability	100%						
0	Threat resistance	100%						
0	Security	100%						